DEVELOPMENT OF AN ENGINEERING AND COST ANALYSIS OF A SHIP-MOUNTED SURFACE COLLECTOR SYSTEM

Final Report

Submitted to:

Mr. Carroll D. Day
Contracting Officer
U.S. Department of the Interior
Minerals Management Service
Technology Assessment and Research Branch
12203 Sunrise Valley Drive, MS635
Reston, VA 22091

by:

STEWART TECHNOLOGY ASSOCIATES
5011 Darnell
Houston, TX 77096
Tel: (713) 665-7294
Fax: (713) 665-1424

on behalf of:

Veritec Marine Technology Consultants
a Division of
Veritas Technical Services (USA) Inc.
1325 South Dairy Ashford, #300
Houston, TX 77077

November 1987

EXECUTIVE SUMMARY

A system for the surface collection of oil from a blowout at sea has been engineered and costed. This system is based upon a configuration previously defined by the MMS. The system consists of a principal collection and storage vessel, floating booms to gather the oil, towed by service vessels, and skimmers to gather the oil from the water.

The collection and storage vessel is a 90,000 dwt tanker. Cost of a 10 year old tanker is around $5 million, without coastwise privileges, or $30 million with such privileges. Cost of conversion is around $13 million and coastwise privileges are not needed if the vessel is to be used solely for oil collection and processing.

A target collection rate of 30,000 bbl/day of oil is selected and the system is designed to operate continuously offshore for 150 days. Offloading every 20 days is required, or more frequently if tight emulsions cannot be broken offshore and a large percentage of water is also to be transferred. Process equipment and chemical injection are included in the system in order to maximize the probability of breaking tight emulsions.

Costs for operating the system are also provided, based upon scenarios on the West Coast, Gulf Coast and off the New England Coast.

The system is concluded to be feasible and economically sensible, particularly if several operators agree to share in the conversion costs and to form a consortium for oil spill collection and clean up.

Provision is made in the design for off-loading/lightering the stored oil to another tank ship thus allowing the collector ship to remain on station. In excess of 80,000 tons of storage capacity is provided enabling the system to hold 3 weeks of collected oil.

A special feature of this collection system ship is that it has the ability to remain downstream and in close proximity to the surface flare of the sub-surface blowout. The specialized propulsion requirements result in the need for retrofitting of thrusters on the tanker and the additions of oil booms on each side of the ship with all required control and handling equipment. The vessel also has modifications in the form of specialized fire suppression and ventilation equipment because of the close proximity of operations to the blowout site.

In a literature review undertaken prior to the commencement of the engineering and cost analysis, several possible general configurations for a suitable ship-mounted surface collector system were defined. In this report, an engineering analysis is performed of a system based upon one general configuration, with one boom type selected. The additional use of skimmers is also provided for.

Sufficient engineering is performed to enable reliable costing of the system to be undertaken. Major factors affecting the cost of producing the system are the cost of the tanker and it conversion. The tanker cost is itself dependent upon the need for coastwise privileges. The major factor affecting operational costs is the strategy for utilizing the tanker when it is not required for surface collection work.

2.0 ENGINEERING ANALYSIS - INTRODUCTION

No detailed specification for the ship-mounted system existed prior to this project and it was not the purpose of this project to develop such a specification. Instead this project is based upon a general outline specification and is necessarily open ended in places. It is suggested that the operating strategy for the primary vessel when it is not used for surface collection of oil is the principal key to the success of the concept. As part of this strategy, it is considered important that the system is available for deployment anywhere in the coastal waters of the USA, but that the California waters have first priority. This means that the vessel should be stationed somewhere close to, or in Californian waters, but that she should be able to get through the Panama Canal in order to perform collection operations in the Gulf of Mexico, or anywhere else along the Eastern Seaboard. The possibility of chartering the vessel to operate on foreign oil spills and blowouts should also be maintained.

the tanker are unaffected. Special safety and fire fighting/suppressing systems will enhance the vessel. The addition of one tunnel type bow thruster, one tunner type stern thruster, and a helideck aft will also enhance the vessel.

The most important consideration is the mode of operation. It is proposed that the Ship's Master and key members of the crew are provided with comprehensive training in oil collection and in oil spill cleanup operations. Immediately after commissioning the vessel, at least 10 days should be set aside for sea trials and for crew training. Then every six months at least three days should be set aside for refresher training which should take place on board the vessel and should involve outside experts with classroom presentations, mixed with full-scale maneuvers. All equipment should be deployed, preferably in conditions around Beaufort 5. Communications with a shore base and with other vessels and aircraft should be practiced. Real oil should be spilled and collected when permissible.

In a real situation, the following possibilities exist:

a) The primary vessel could be in port somewhere either loading or discharging.

b) The primary vessel could be in transit in ballast.

c) The primary vessel could be in transit fully laden.

Ideally, she should proceed straight to the blowout and begin operations. However, it may be more prudent to completely discharge the cargo first, unless another tanker capable of offloading her can be at the blowout simultaneously. In this case the oil collection can start immediately and the collected oil can be placed into the main cargo tanks.

Obviously much depends upon the blowout rate, the blowout location and the location of the collection vessel. It will certainly be important to maintain a list of available tankers to fulfill the offloading and transport role. Such tankers may be currently laid up, they may be in the U.S. Navy or they may be on short or long-term charters, but prepared to enter operations in an emergency.

Transfer of key personnel to the collection vessel would be primarily by helicopter. The helicopter should also be retained for tracking oil slicks, directing the oil recovery vessel to the optimum location at the clean up site, and for emergency transport of personnel to shore.

In the event of a blowout, certain key logistics are anticipated which are beyond the scope of this report to describe in detail. Broadly, there must be one Director of Operations and one U.S. Coast Guard On-Scene Coordinator (OSC). This Director of Operations may be appointed by the oil company or drilling contractor responsible for the blowout. He or she may be from the staff of that company or from another organization. He could be the OSC appointed by the Coast Guard. In any event, this person will be concerned with chartering vessels and planes, liaising with Merchant Marine, U.S. Navy and Coast Guard personnel and vessels. He or she may also elect to be located for the duration of the collection project on board the primary collection vessel. Alternatively, he or she may elect to have a deputy stationed on the vessel to direct offshore operations, or the captain of the collection vessel may be delegated this role. The last option is recommended, provided that full and complete training in such operations has been given to the captain.

It should be possible, as the system is shown to be feasible, to get the major oil companies into a typical club or co-op arrangement where they agree to cooperate in the event of a blowout. Operations of such a club would include existing tanker fleet operations in general and ideally spm operations as well, such that an offloading and transport tanker could be made available quickly.

One of the oil companies would have to take a lead role in owning and operating the collection vessel. The cost of operating the system in oil cleanup operations would be established in advance, and probably revised each year. In the event of a blowout occurring to any company in the club, this company would have first priority on the collection vessel and the club would make its best efforts to provide this company with the offloading and transport vessel too. In this way the club would recover initial investment and operating costs in the system. In the event of a foreign blowout or a blowout occurring to a company outside the club, the oil company operating the primary vessel could set their own fees for assistance.

If Government enthusiasm for the project was to carry into the oil companies, it is possible that primary collection vessels could be converted and kept in regular trading routes on both East and West Coasts. This would reduce time to reach blowouts wherever they were to occur.

The above described operating strategy and logistics are illustrated in figure 2.1.1

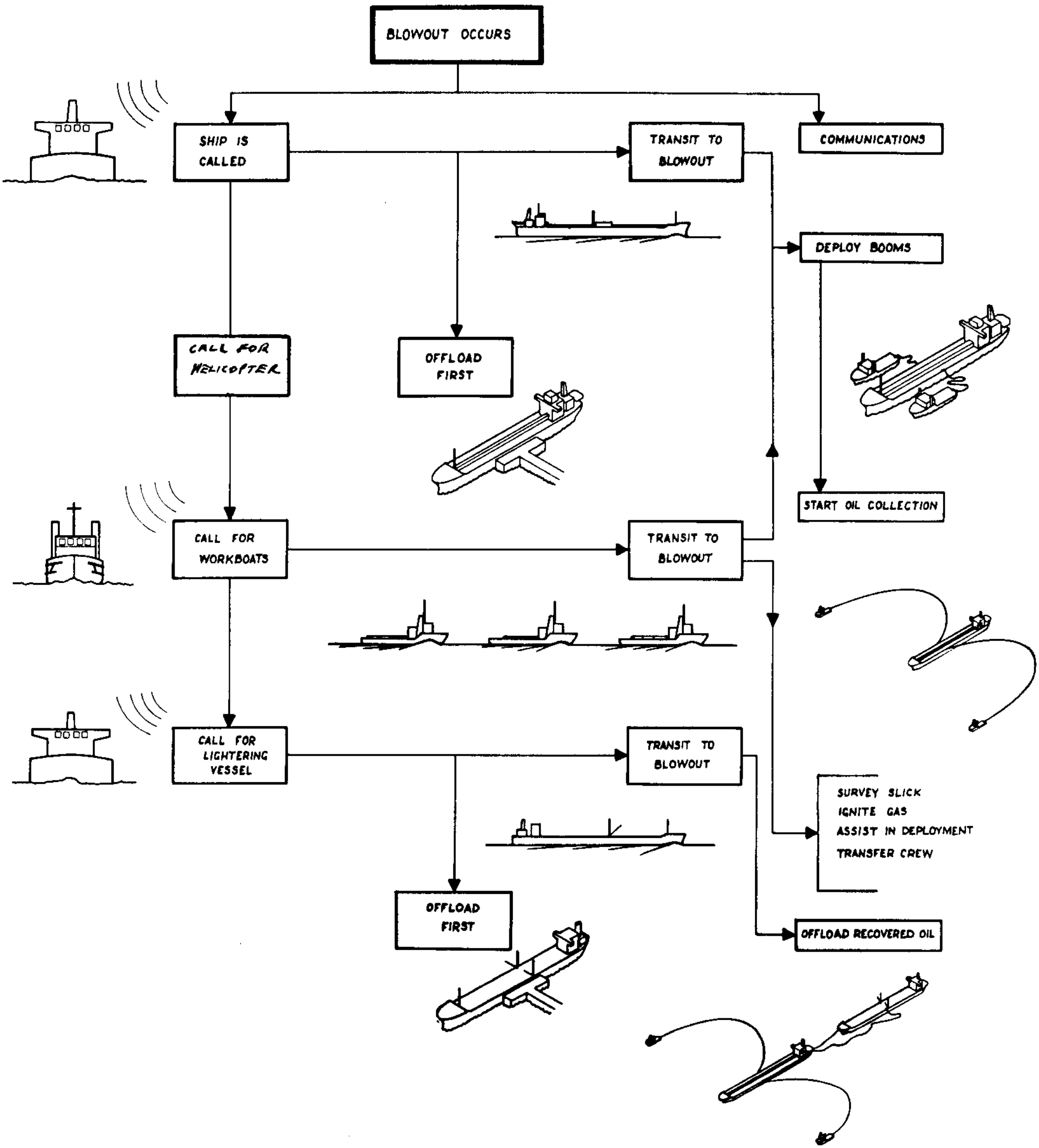


Figure 2.1.1

OPERATING STATEGY AND LOGISTICS

2.2 SELECTION OF A SUITABLE TANKER

The success of the surface collection system will depend to a large degree upon the initial cost of such a system. It is proposed in this document that operating costs when the system is not in use are minimal. When the system is in use, the first operation could pay for the initial investment.

If an oil company was to operate the primary vessel, the need for coastwise trading privileges would be dictated by the trading practices of this company. For the purposes of this document, it is assumed that such privileges are unnecessary.

The requirements for the tanker to be selected for conversion to a storage vessel for oil collected during a blow-out are:

Size:	80,000 -	100,000 dwt	
Length:	L	--	250m
Breadth:	B	--	30m
Draught:	d	--	12m
Age:	Not more than 10 years old		

This study has focused upon U.S. flag vessels, although some references are given to available foreign flag vessels as well.

The world's tanker fleet has been reduced from about 323 million dwt in Jan. '81 to about 265 million dwt in Jan. '85, a reduction of 18%. Of these figures, 6 million dwt were laid up tankers in Jan. '81, and 49 million dwt in Jan. '85. The number of tankers in lay-up, however, has decreased 20% since Jan. '83. The scrapping rate is still very high, at 7-8% dependent on tanker size. For tankers of size 80,000 - 160,000 dwt, the scrapping rate is lower, at 3-4% in Jan. '85.

The market value for tankers worldwide has shown a downward trend over the last years (See Table 1 and Fig. 2.2.1, taken from reference 1).

The 1987 tanker prices are depressed further as a consequence of the 1985-1986 decline in the price of oil. However a $5 million price for a 10 year tanker is still reasonable, for a tanker that is in a good state of repair, with well maintained equipment.

	END 80	END 81	END 82	END 83	END 84
T/T 350,000 dwt, built 1975	25.00	10.00	4.50	5.75	6.00
T/T 280,000 dwt, built 1974	16.00	7/7.50	3.50	5.00	4.5/5
T/T 220,000 dwt, built 1972	8.00	4.00	2.15	3.00	3.5/5
M/T 135,000 dwt, built 1975	19.00	13.00	7.00	9.25	6.5/7
M/T 100,000 dwt, built 1967	7.00	2.50	2.00	2.50	2.2/5
M/T 80,000 dwt, built 1980	--	--	14.00	16.00	13.00
M/T 60,000 dwt, built 1980	--	--	14.00	15.00	10/11.00
M/T 32,000 P/C dwt, built1974	16.00	9/10.00	7.00	8.50	6.00

Table 1. Market values for tankers
End Year prices in mill$
(From ref. /1/)

T/T = Turbine powered tanker
M/T = Conventional diesel powered tankers. (Steam turbine will be typically 15% cheaper).

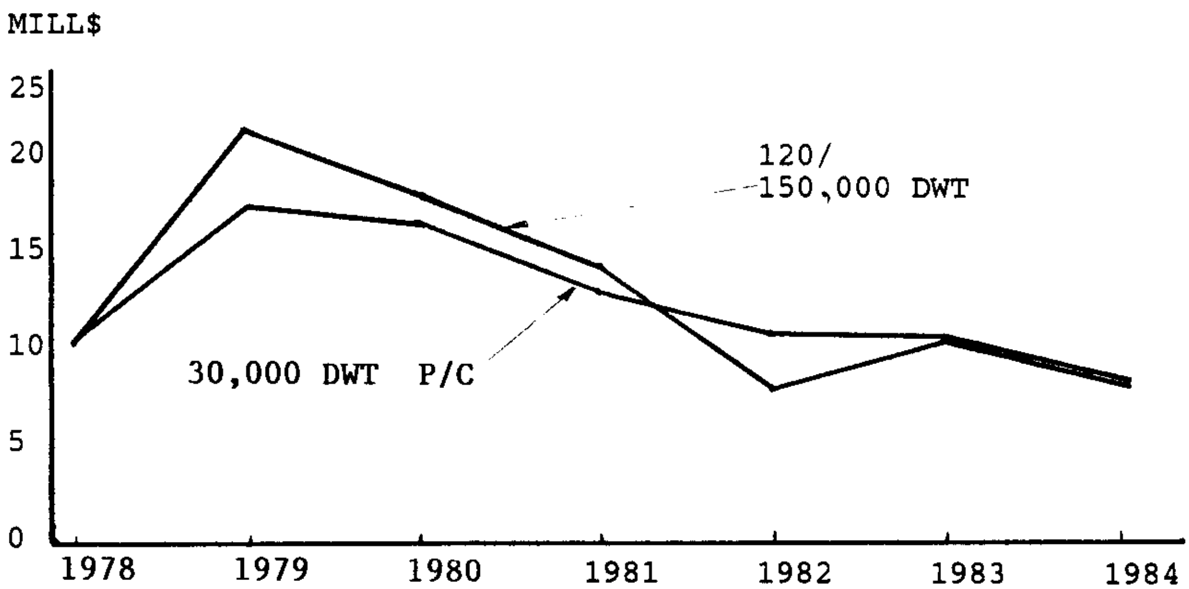


Fig. 2.2.1 Market values of tankers - 5 years old
(From ref. /1/)

The availability of tankers for the purpose of conversion was investigated by contacting ship brokers. For U.S. flag vessels there is a jump in size of available tankers from about 92,000 dwt to about 120,000 dwt. A factor that greatly determines the price is the question whether or not the vessel needs to have "coastwise privileges" (Jones Act). A vessel with these privileges can go from one U.S. port to another and load or unload cargo, whereas a vessel without such privileges can only go from one U.S. port to a port in a foreign country.

The available 120,000 dwt tankers have such privileges, which puts their value up to about $30 mill. A few available vessels do not have such privileges, and the market value of these is around $5 million. For a vessel being used as a collection and storage facility, not in coastwise trade, it is considered that coastwise privileges are not necessary. At the time of writing, there are a few sister ships on the market, around 92,000 dwt with U.S. flag and worth roughly $5 million each. Importantly, these vessels are also able to pass through the Panama Canal.

Main data of these vessels are given in Table 2 (source: ref. /2/).

Further information about the vessels is considered to be confidential, and can only be released with approval from the owner.

Length over all:	894' (272.5m)
Length between perpendiculars:	855' (260.6m)
Breadth moulded:	105'-9" (32.2m)
Depth:	64'- 6" (19.7m)
Draught:	49'- 1" (15.0m)
Displacement:	106,000 l. tons
Deadweight:	92,000 l. tons
Year Built:	1976/1977
Machinery:	Steam turbine

Table 2. Main particulars of vessel

If one should choose a foreign flag vessel, the number of available ships are much larger. The information below is taken from Fairplay Magazine (April 25th, 1985) and Lloyd's List (April 30th, 1985) show three other tanker vessels of the desired size for sale, with prices ranging from $2.3 million (scrap) to $5.5 million. Information on other ship sales at the time of writing provided confirmation of this typical price range.

25th April 1985 **FAIRPLAY**

Eirama. - The British flag motor tanker **Eirama (ex-Thorshovdi) owned by Intersea Investments Ltd., (H. C. Sleigh) Bahamas, has been reported as sold to Greek interests for a price in the region of $2.4m. Details:** Single deck, 54,540 grt. 104,447 dwt, built by Mitsui Sb & Eng Co., Ichihara and Tamano, in 1968, with a two-stroke, single-acting, ten cylinder B&W engine (23,000 bhp) giving about 14.5 knots.

Kaisei Maru. - The Panamanian-flag motor tanker **Kaiser Maru** (ex-**Keiyo**) owned by Takebayashi Kisen KK, Wakayama has been reported as sold a A Alafouzos (Glafks Shpg), Athens, for a price in the region of $5.5m. **Details:** Single deck, 44,605 grt, 87,452 dwt, built by Koyo Dockyard Co. Mihara, in 1975, with a two-stroke single-acting, six-cylinder B&W engine (20,5000 bhp) built by Mitsui Sb & Eng Co., Tamano, giving about 15.75 knots.

30th April 1985 **LLOYD'S LIST**

Eirama (ex-Thorshovdi) - Motor tanker; 104,447 tonnes dw, 54,540 gross. Built Ichihara, 1968. Sold by Thor Dahl of Sandefjord to Greek interest under private terms. Market sources suggest a price of around $2.5m was paid.

However, for the purpose of conversion, the purchase price is less important as long as the average price is kept say around $5 mill. A less expensive vessel may be badly maintained, so additional cost will be required for bringing the vessel into a seaworthy condition.

The general arrangement, shown in figure 2.2.1., for the selected vessel is to be regarded as generic although it is based upon the actual general arrangement drawing and tankage plans of a vessel currently available for sale.

References:

/1/ R. S. Platou: The Platou Report, March 1985
/2/ A. L. Burbank & Co. Ship Brokers

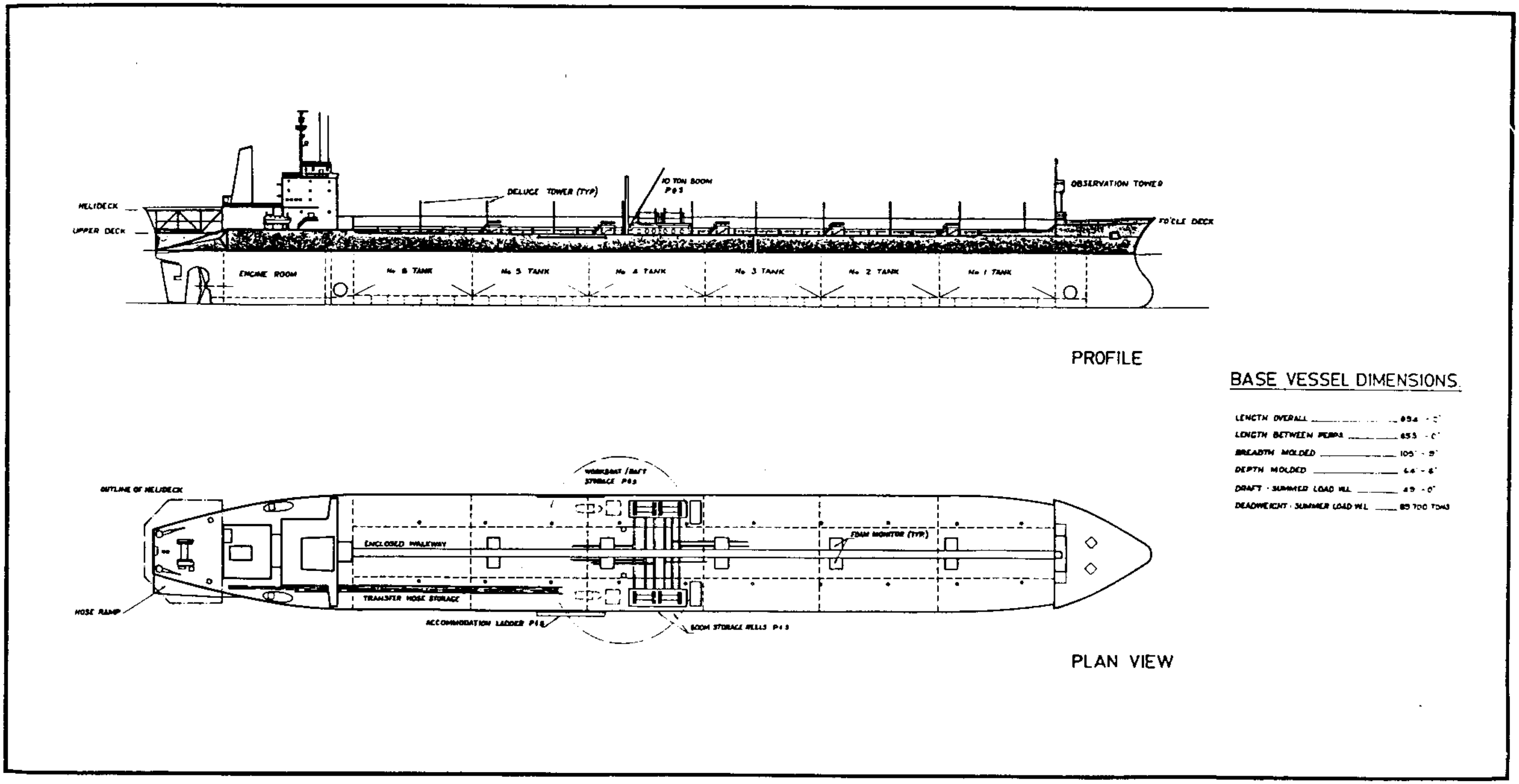


Figure 2.2.1
GENERAL ARRANGEMENT AND DIMENSIONS
OF SELECTED "GENERIC" TANKER

2.3 SHIP MOTIONS

Motion response characteristics for similar tanker vessels have been obtained from in-house reports and been used to estimate the motions of the actual vessel selected for this study. The main particulars of this vessel are:

Length over all:	894' (272.5m)
Length between perpendiculars:	855' (260.6m)
Breadth moulded:	105'-9" (32.2m)
Draught (loaded):	49'-1" (15.0m)
Displacement (loaded):	106,600 l. tons
Deadweight	92,000 l. tons
Block coefficient:	0.85
Est. ballast draught:	27'(8.3m)
Displacement (ballast):	56,600 l. tons

The ballast draught is roughly estimated from similar vessels, and the motion response characteristics have been estimated for both draughts.

Presented here are:

(1) Response Amplitude Operators (RAO's) for vertical motion (Heave, roll, pitch) about the Centre of Gravity (C.G.) of the vessel, (Fig. 2.3.1 - 2.3.6).

The RAO's are made dimensionless as follows:

Heave:	Heave motion amplitude divided by wave amplitude (A).
Roll and Pitch:	Motion amplitude (rad.) divided by half wave steepness = wave amp./ wave length (LAMBDA).

The RAO's are given as functions of wave length divided by ship length (L=Lpp, length between perpendiculars).

(2) Significant Response Amplitude Operators (short term response) for motion, velocity and acceleration at a point at the deck corner amidships (Fig. 7-24), chosen at the position of attachment for the booms. The motions are calculated in vertical, trans- verse and longitudinal direction at this point.

The short term response operators are obtained by combining RAO's for the motion with a family of PiersonMoskowitz (P-M) wave spectra. Spreading of wave energy about a given main wave direction is included by using a cosine-squared directionality function (short-crested waves).

The significant response amplitude (R_s) are presented in Figs. 2.3.7 - 2.3.24 in dimensionless form. Note that R_s here represents double amplitudes. The parameter R_s is denoted $\sqrt{8E}$ in the figures, and is presented as $R_s/(H_s/L)$ where H_s is the significant wave height and L is the wave length. Table 1 explains how the response amplitudes are made dimensionless. The response variables are functions of $T_Z \cdot \sqrt{g/L}$, which is a dimensionless form of the average zero up-crossing period T_Z, g being the acceleration of gravity.

For a given sea state defined by H_S and T_Z, the motions at the attachment point can be calculated from these figures. As a result of the computed motion amplitudes, in a wide range of sea states, Beaufort 5 is considered to be the maximum environment at which the booms should be attached. The Beaufort scale is shown in Fig. 2.3.25. For Beaufort 5 the following is selected:

Significant wave height (H_S):	2.5m (8.21 feet)
Wind Speed:	20 knots
Wave Period (T_Z):	7.0 sec.

For this seastate details the motion results at the deck edge are given in Tables 2, 3 and 4. The motion amplitudes (displacement, velocity and acceleration) are presented as maximum values, which are taken as twice the significant values.

VARIABLE	MADE NON-DIMENSIONAL WITH RESPECT TO
Translational motion	L
Translational velocity	gL
Translational acceleration	g
Angular motion	radians
Angular velocity	rad.x$\sqrt{g/L}$
Angular acceleration	rad.x$\sqrt{g/L}$

Table 1. Dimensioning of the short term parameters Rs.

Response	Longitudinal	Transverse	Vertical
	LOAD		
Motion (m)	0.50	0.60	1.50
Velocity (m/s)	0.30	0.40	0.70
Acceleration	0.017g	.019g	0.044g
	BALLAST		
Motion (m)	0.50	1.50	3.00
Velocity (m/s)	0.30	1.00	1.80
Acceleration	0.17g	0.057g	0.100g

Table 2. Max. response at deck edge amidships. Head waves (short-crested).

Response	Longitudinal	Transverse	Vertical
	LOAD		
Motion (m)	0.50	1.40	2.25
Velocity (m/s)	0.30	0.80	1.40
Acceleration	0.017g	0.058g	0.077g
	BALLAST		
Motion (m)	0.50	3.00	4.25
Velocity (m/s)	0.30	1.80	2.40
Acceleration	0.017g	0.115g	0.134g

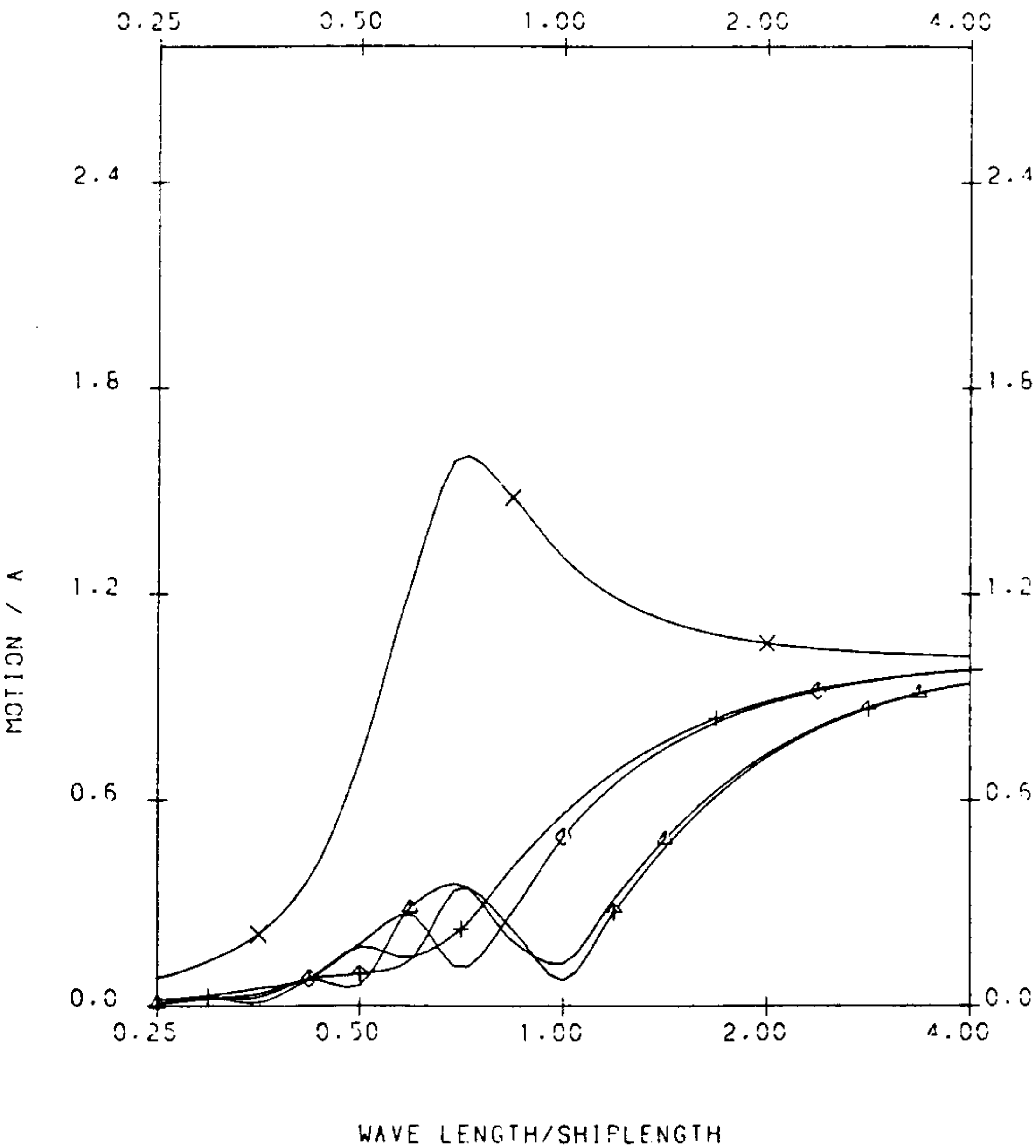
Table 3. Max. response at deck edge amidships. Quartering waves (short-crested).

Response	Longitudinal	Transverse	Vertical
	LOAD		
Motion (m)	0.50	1.90	3.00
Velocity (m/s)	0.30	1.20	1.870
Acceleration	0.017g	0.077g	0.115g
	BALLAST		
Motion (m)	0.50	4.00	5.25
Velocity (m/s)	0.30	2.40	3.20
Acceleration (m/s^2)	0.017g	0.154g	0.173g

Table 4. Max response at deck edge amidships. Beam waves (short-crested).

From the above results, it is concluded that the worst case (as expected) is for operations in beam waves when a maximum of 5 meters heaving (caused by roll coupling) occurs at the deck edge, when the ship is in ballast. This reduces to a 3 meter maximum for fully laden vessel. Therefore, during boom deployment and retrieval operations, the ship should be full. Hence a contingency plan should be prepared to fill cargo tanks with water in the event that boom handling difficulties are encountered. Beam seas should also be avoided, if possible, by use of the dp system. Where a swell exists, perpendicular (or at any large angle) to the wind driven seas, the tanker skipper should experiment with vessel heading in order to select a heading which enables him to provide a sheltered lee for boom deployment, while keeping vessel motions as small as possible. The best result will almost certainly be with the ship in a fully laden condition.

With head seas, even when the vessel is in ballast, motion response is found to be much lower. Boom handling should be relatively easy on the collection vessel, but no sheltered lee can be offered to the smaller vessels (see Section 2.5). It is considered feasible to handle booms and equipment with overall motions up to, but not exceeding, those found for the ship in fully laden condition, in beam seas in Beaufort 5 conditions. With a ballast condition, the beam seas motions are considered too dangerous for boom deployment in sea states above Beaufort 3.



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

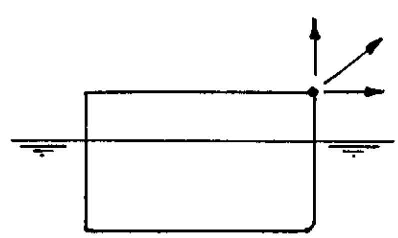
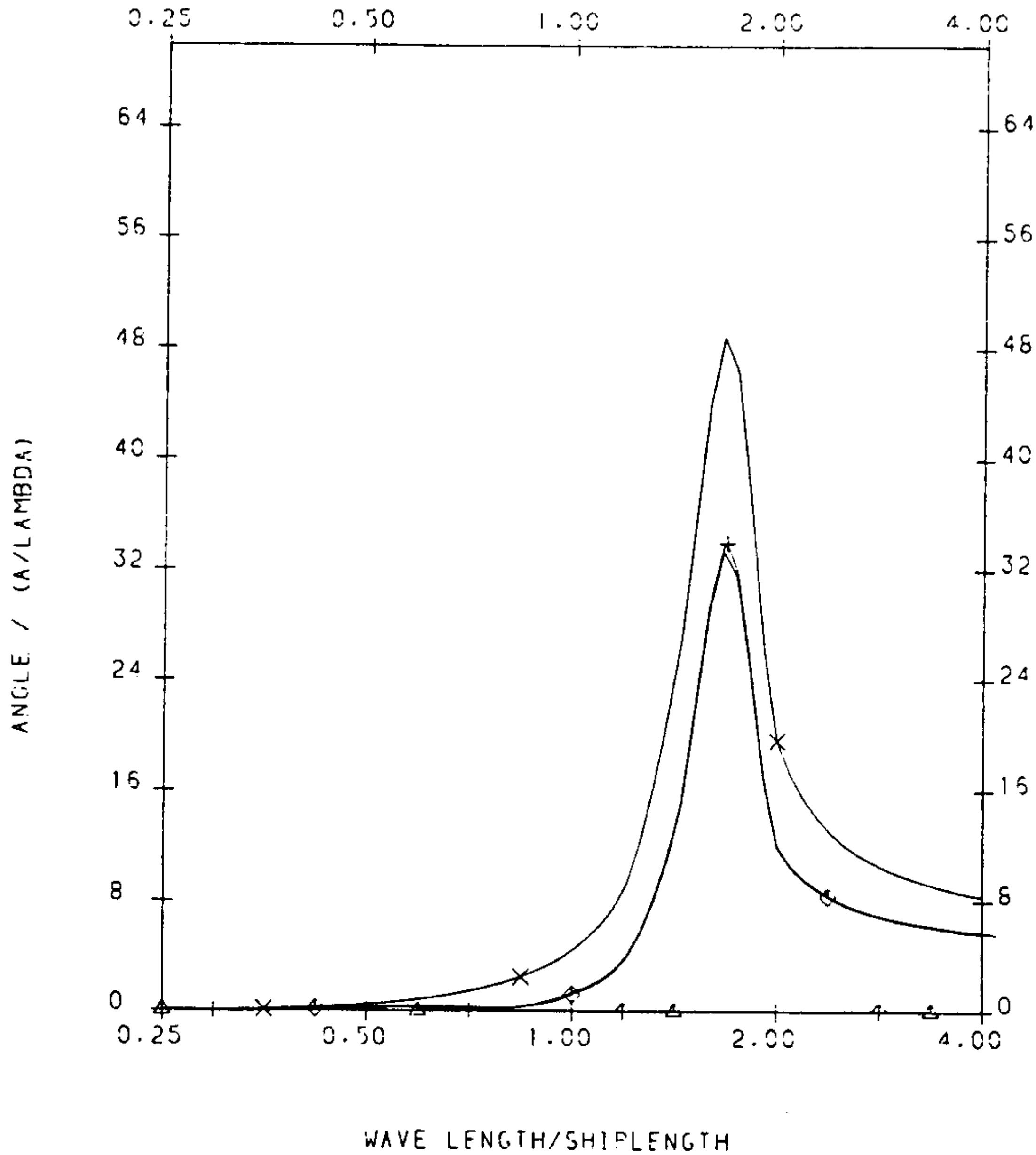


Figure 2.3.1 Heave RAO (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- △ 000.00 (head seas)
- + 045.00 (quartering on bow)
- × 090.00 (beam seas)
- ◇ 135.00 (quartering on stern)
- ↑ 180.00 (stern seas)

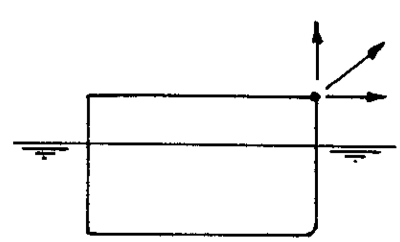
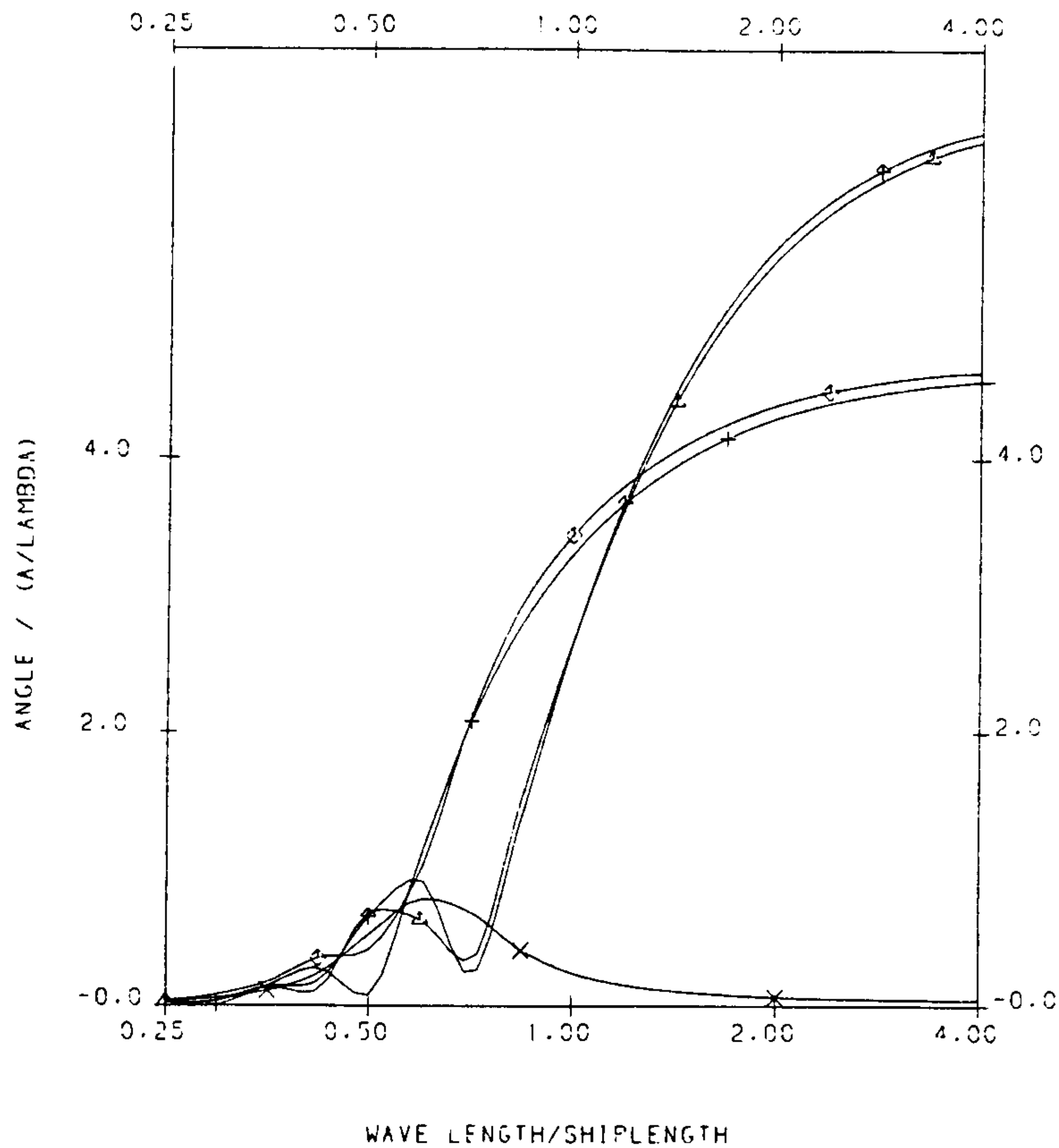


Figure 2.3.2 Roll RAO (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

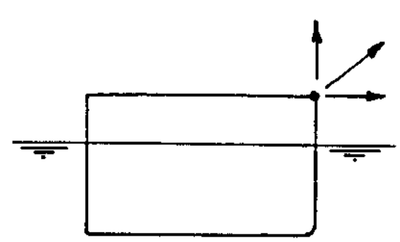
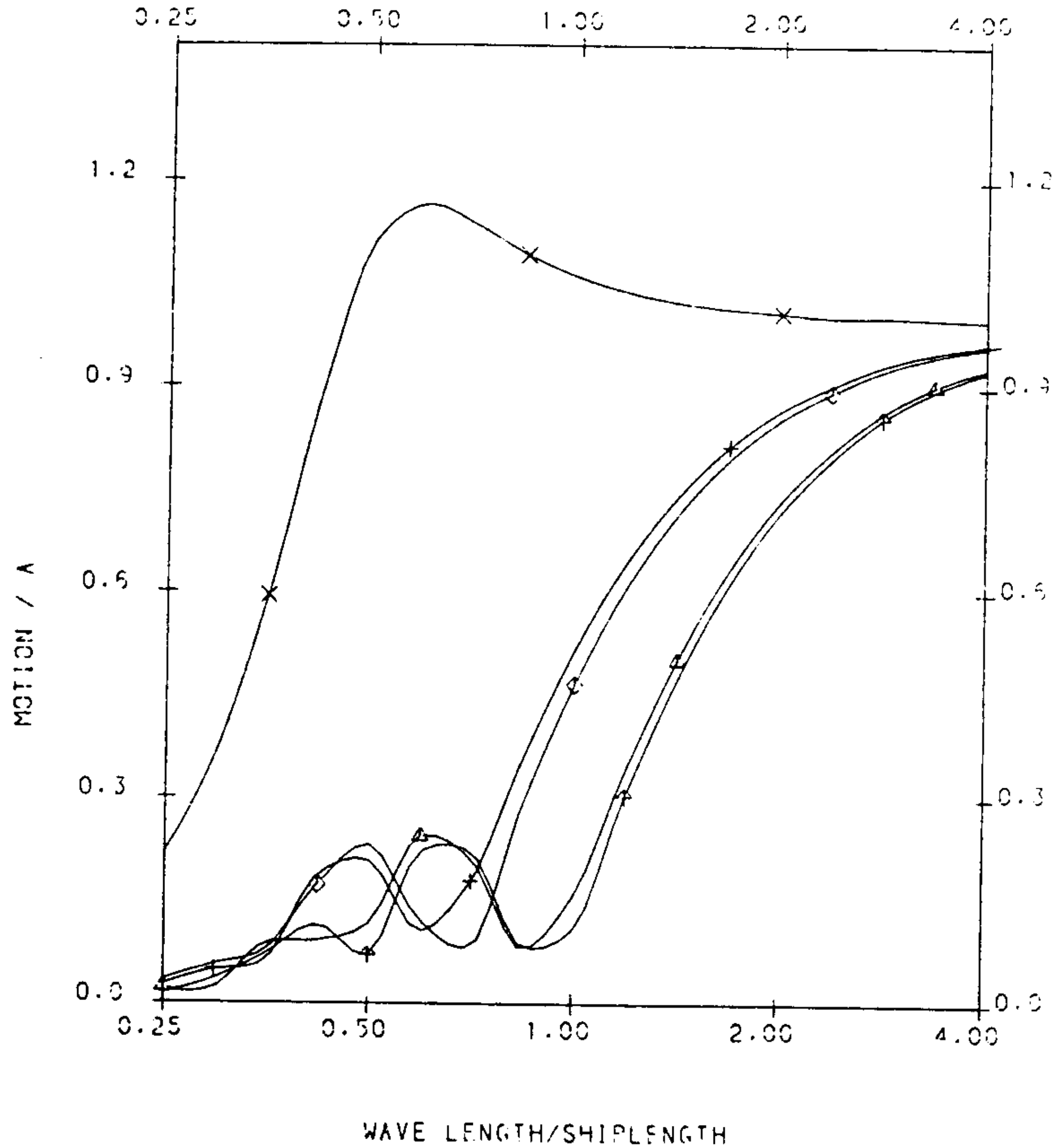


Figure 2.3.3 Pitch RAO (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

—△—	000.00 (head seas)
—+—	045.00 (quartering on bow)
—×—	090.00 (beam seas)
—◇—	135.00 (quartering on stern)
—↑—	180.00 (stern seas)

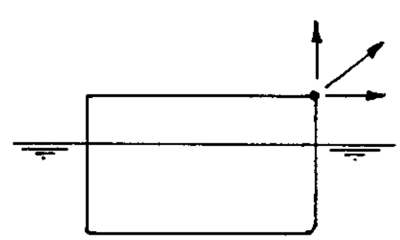
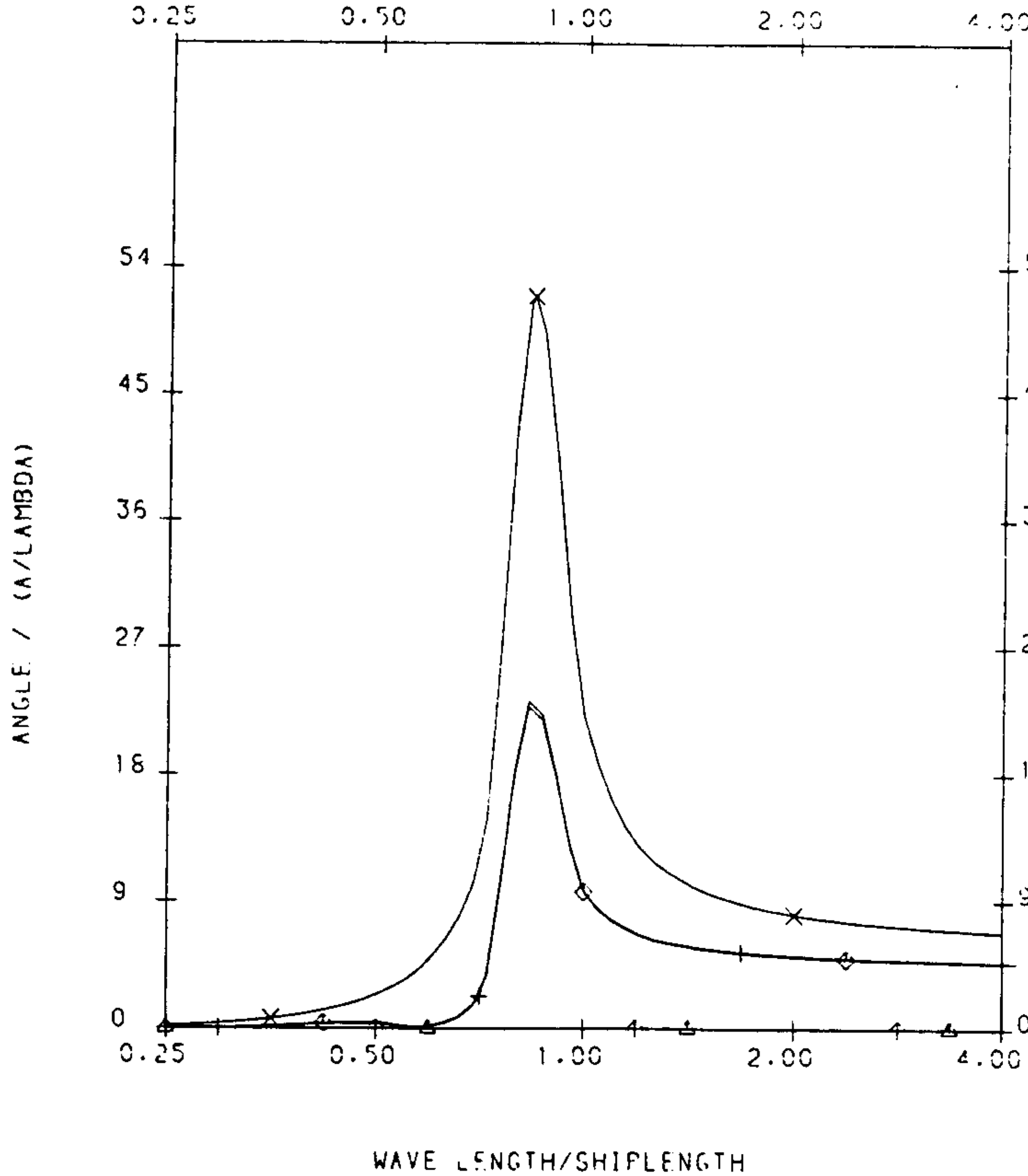


Figure 2.3.4 Heave RAO (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

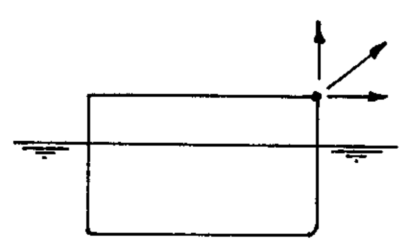
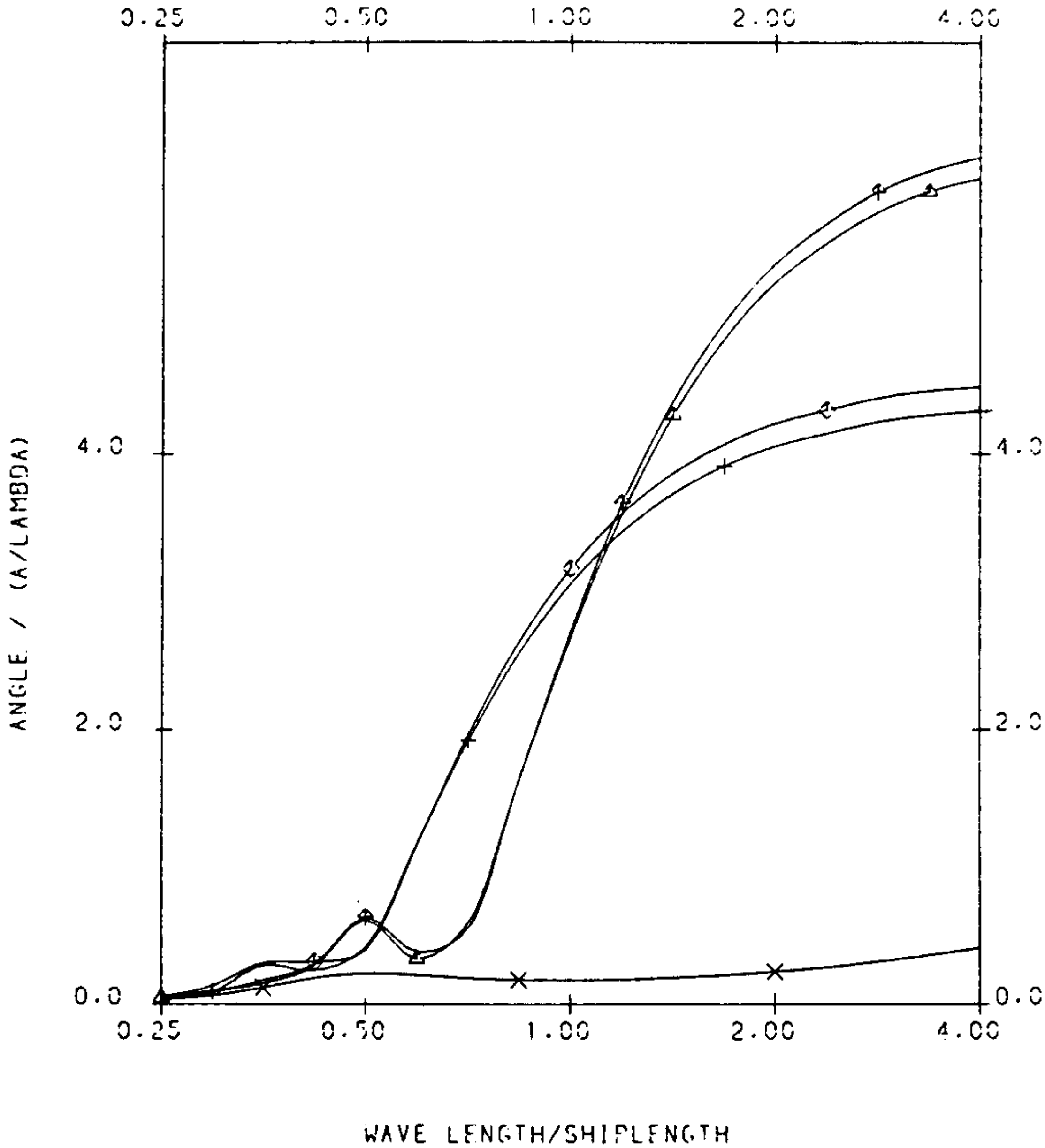


Figure 2.3.5 Roll RAO (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

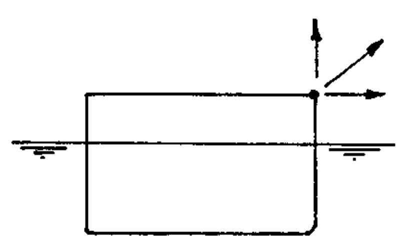
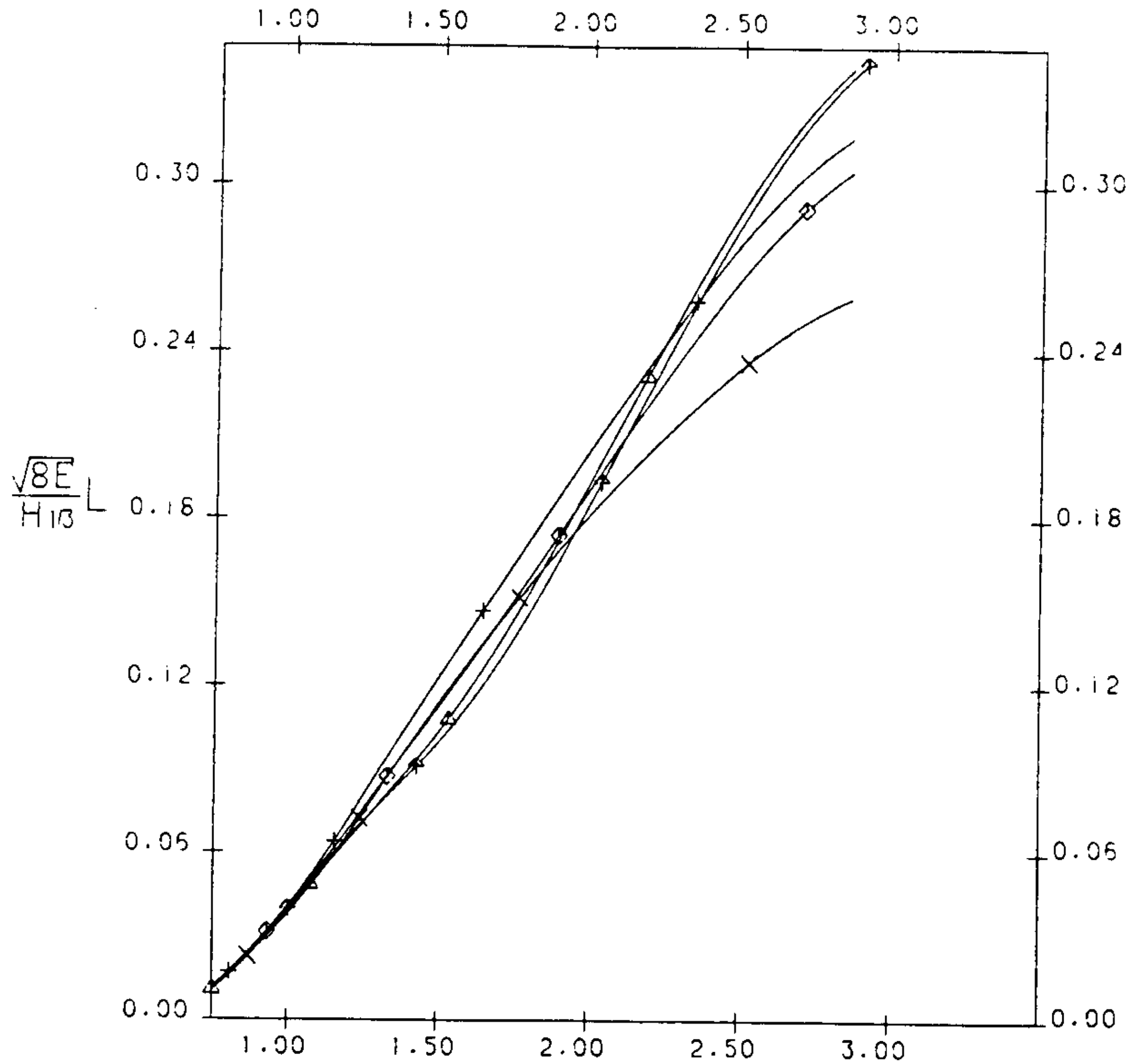


Figure 2.3.6 Pitch RAO (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- △ 000.00 (head seas)
- + 045.00 (quartering on bow)
- × 090.00 (beam seas)
- ◇ 135.00 (quartering on stern)
- ↑ 180.00 (stern seas)

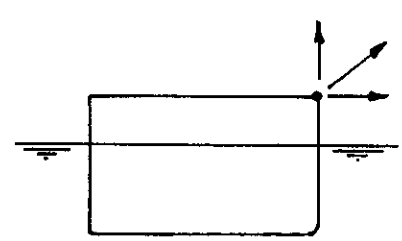
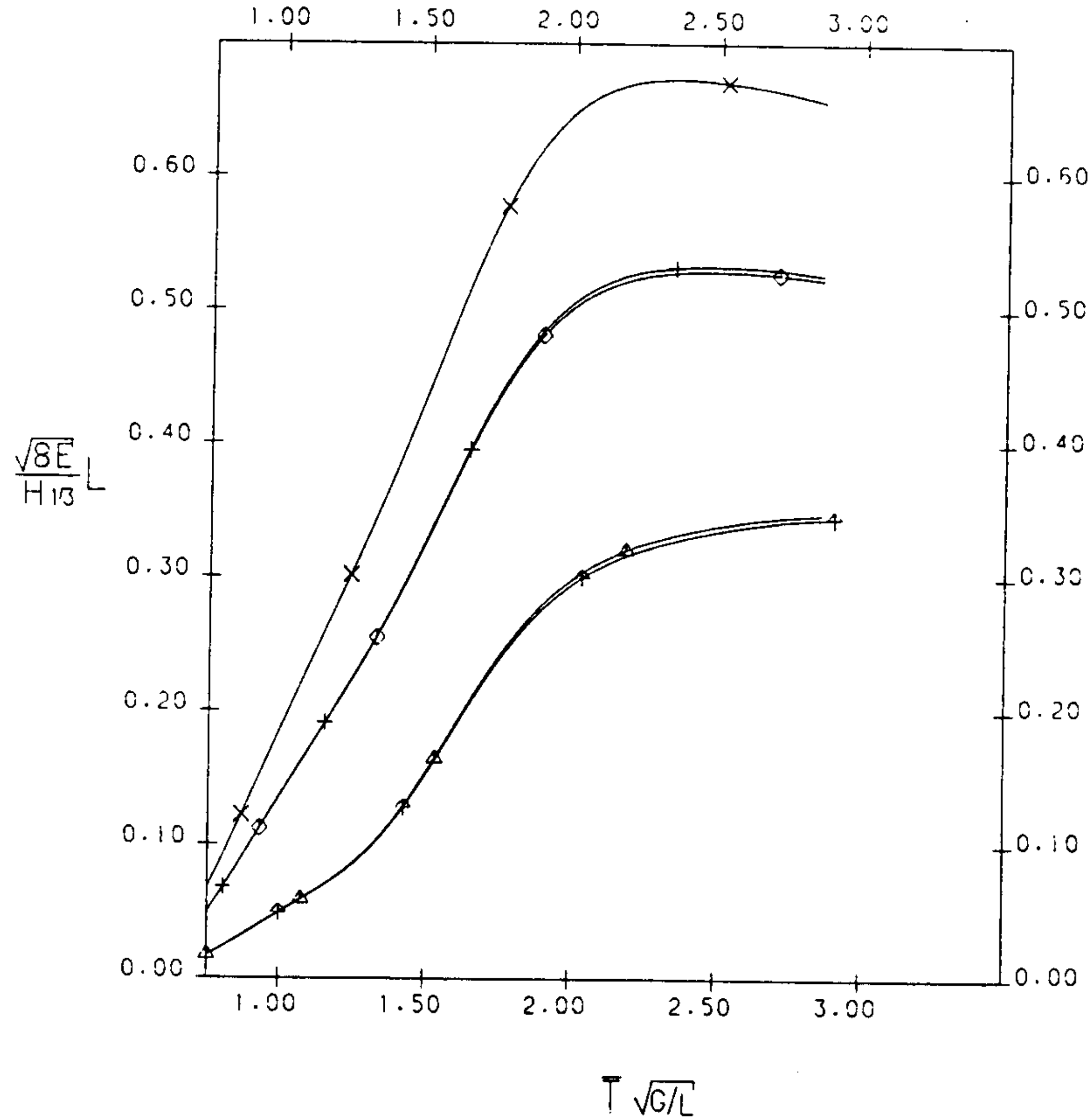


Figure 2.3.7 Surge displacement response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

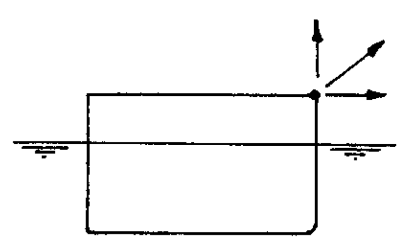
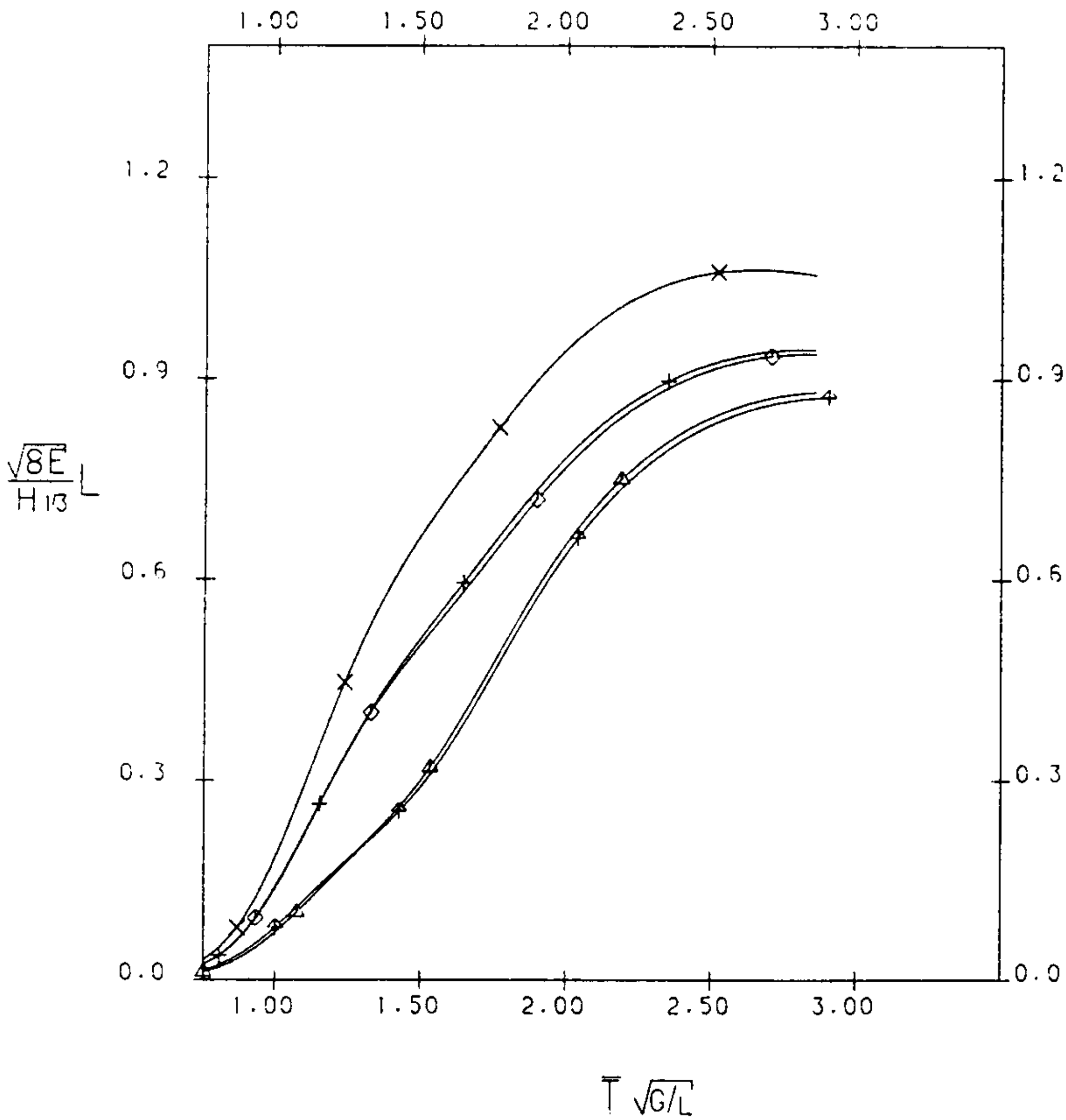


Figure 2.3.8 Sway displacement response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

000.00 (head seas)

045.00 (quartering on bow)

090.00 (beam seas)

135.00 (quartering on stern)

180.00 (stern seas)

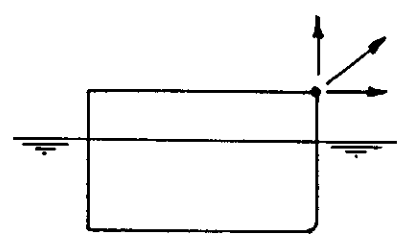
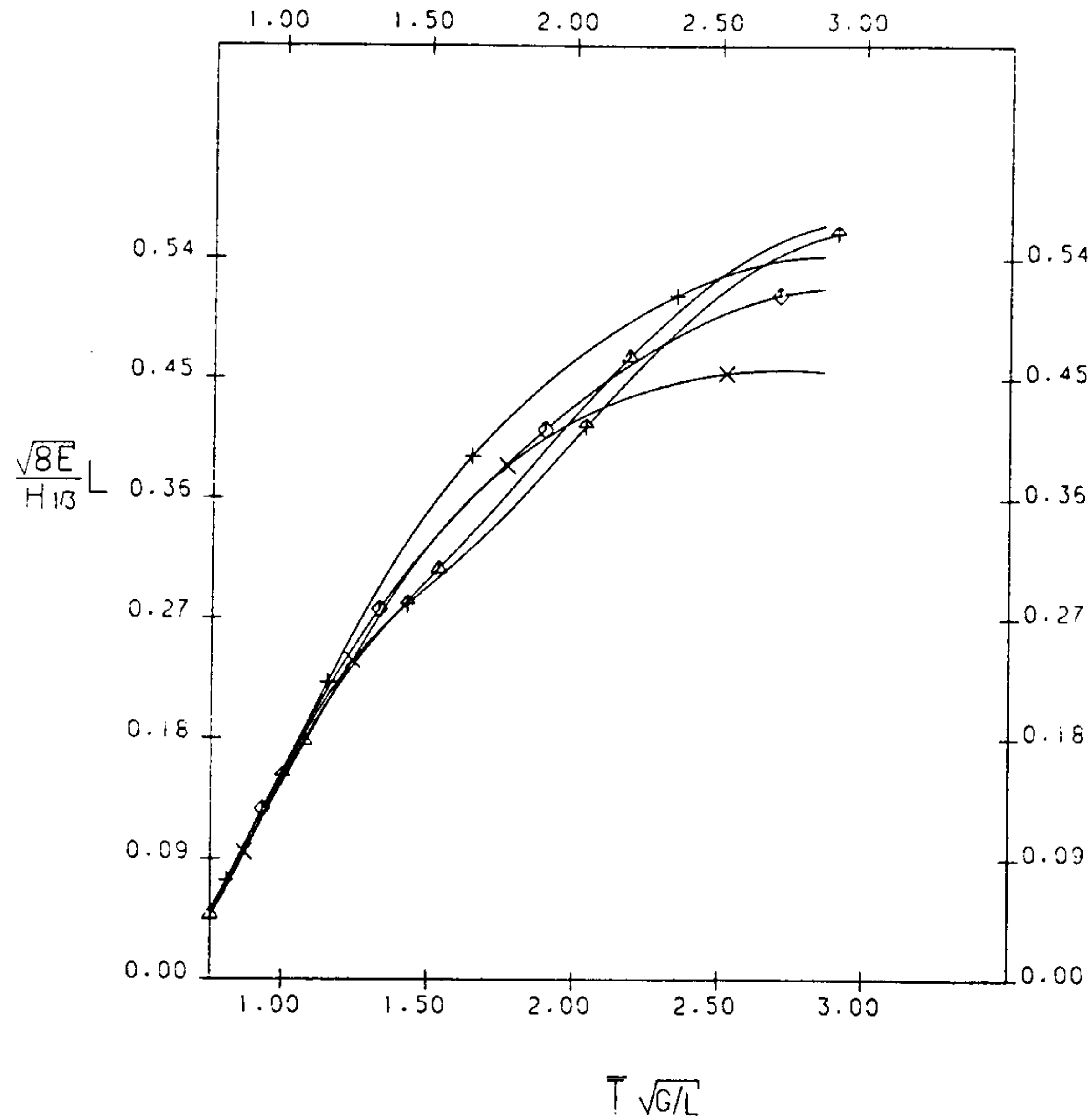


Figure 2.3.9 Heave displacement response (loaded)



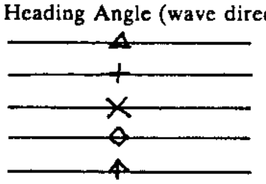
NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)



000.00 (head seas)

045.00 (quartering on bow)

090.00 (beam seas)

135.00 (quartering on stern)

180.00 (stern seas)

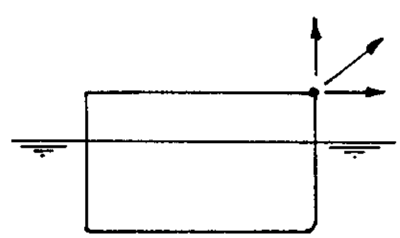
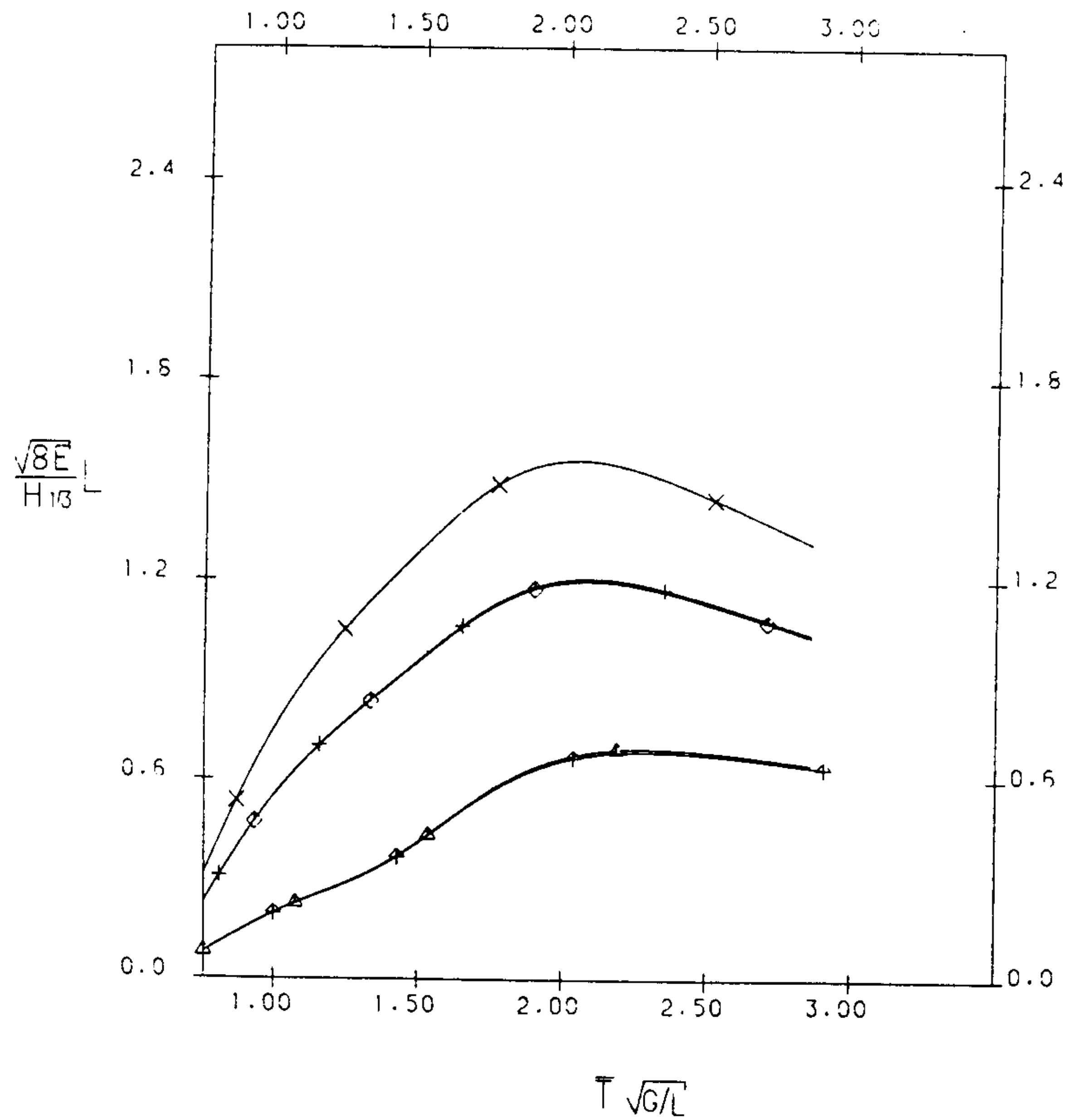


Figure 2.3.10 Surge velocity response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

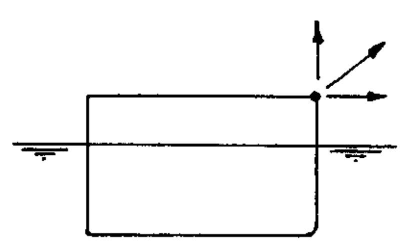
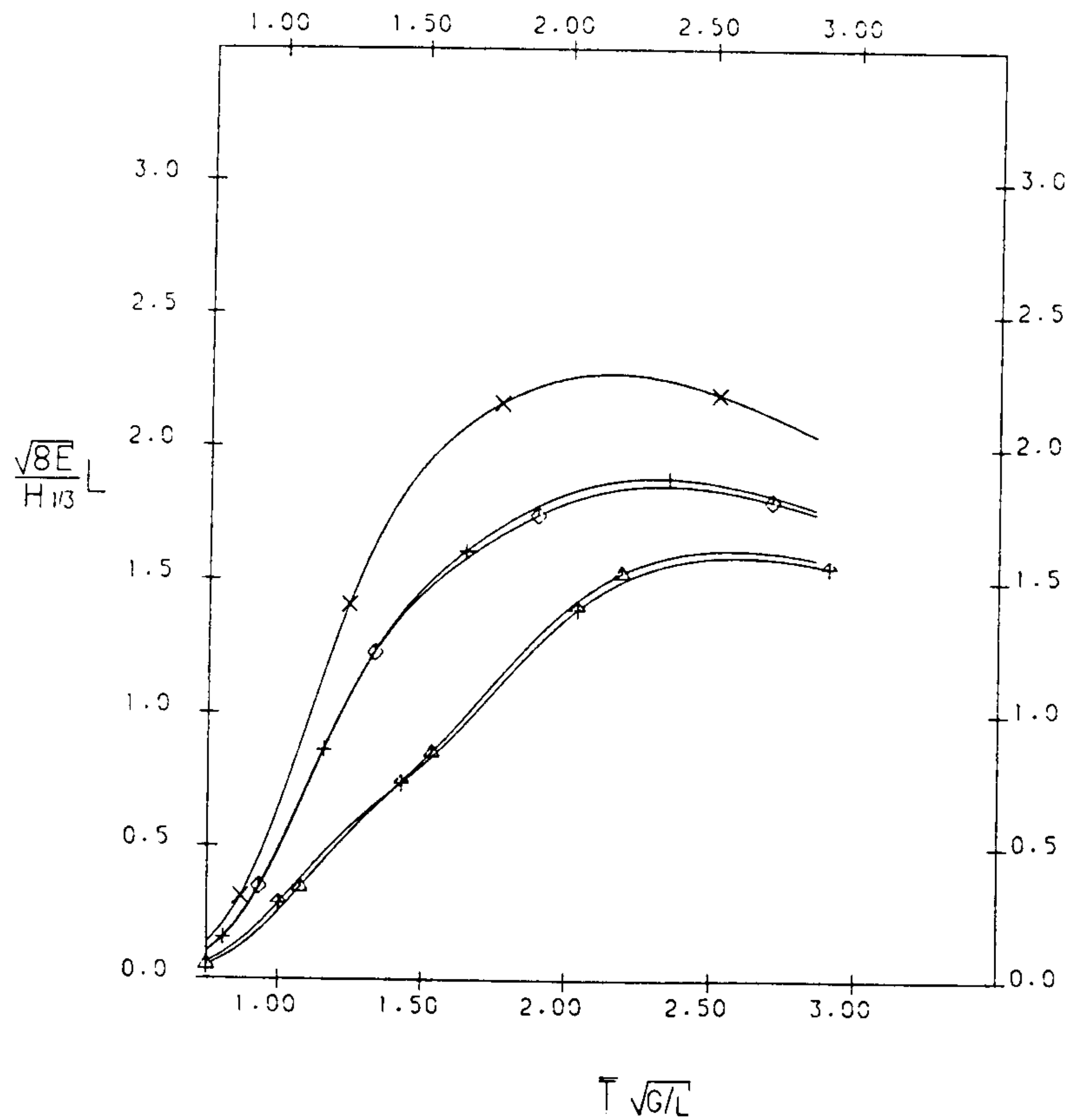


Figure 2.3.11 Sway velocity response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

000.00 (head seas)

045.00 (quartering on bow)

090.00 (beam seas)

135.00 (quartering on stern)

180.00 (stern seas)

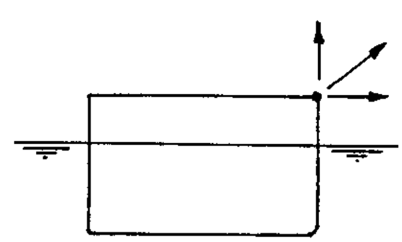
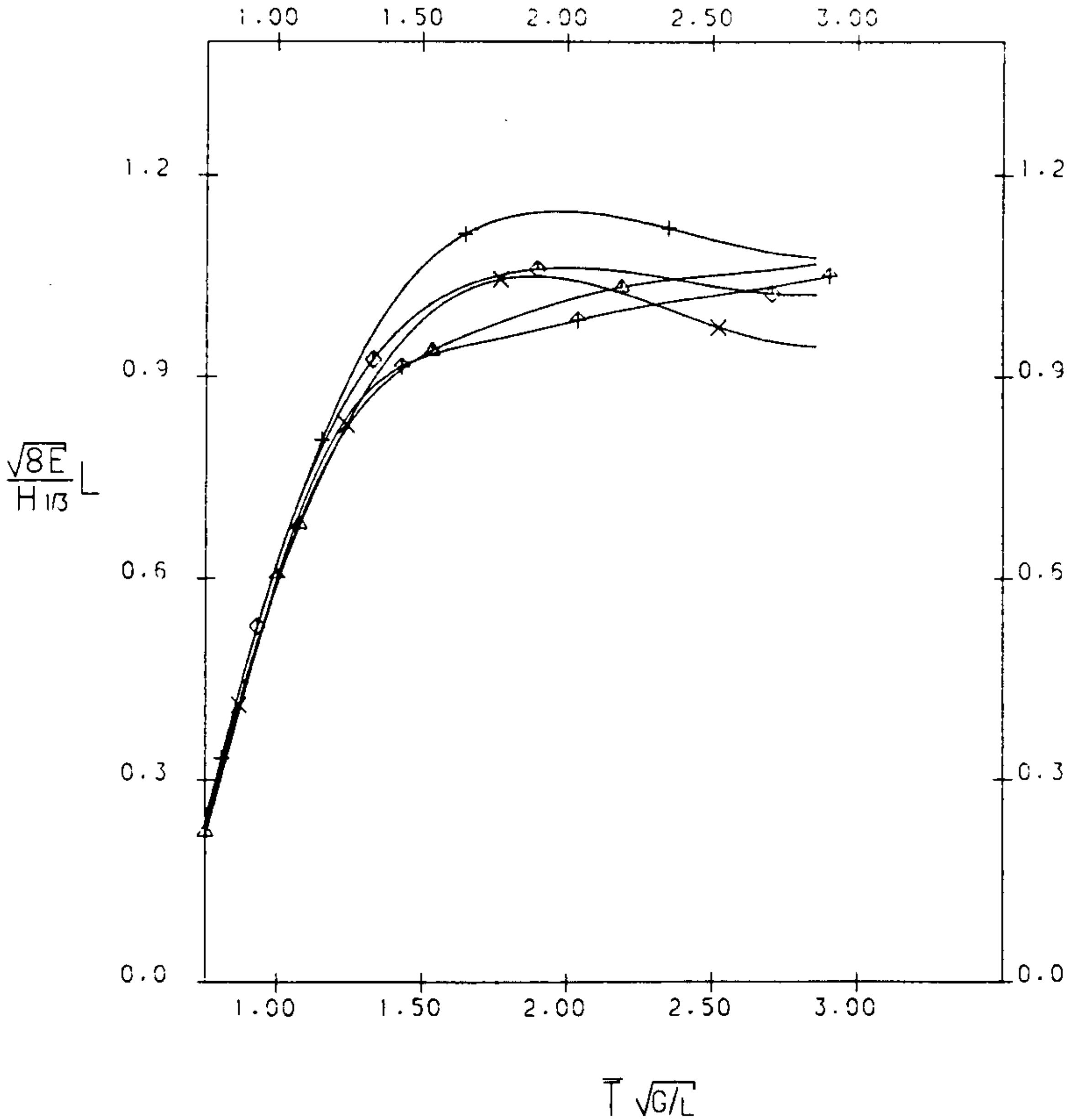


Figure 2.3.12 Heave velocity response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

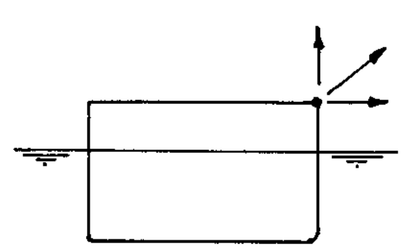
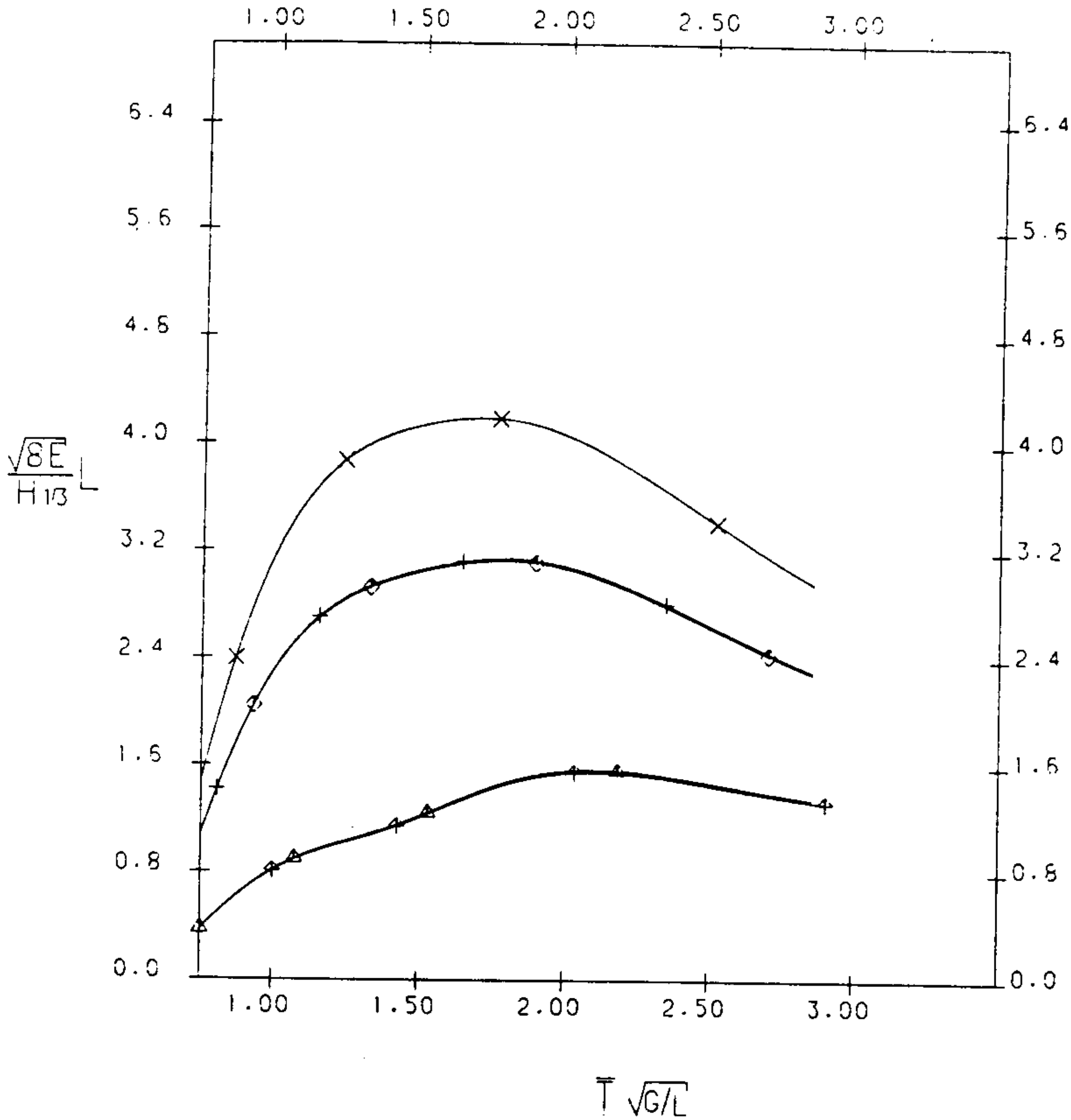


Figure 2.3.13 Surge acceleration response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

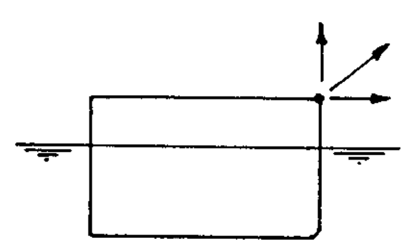
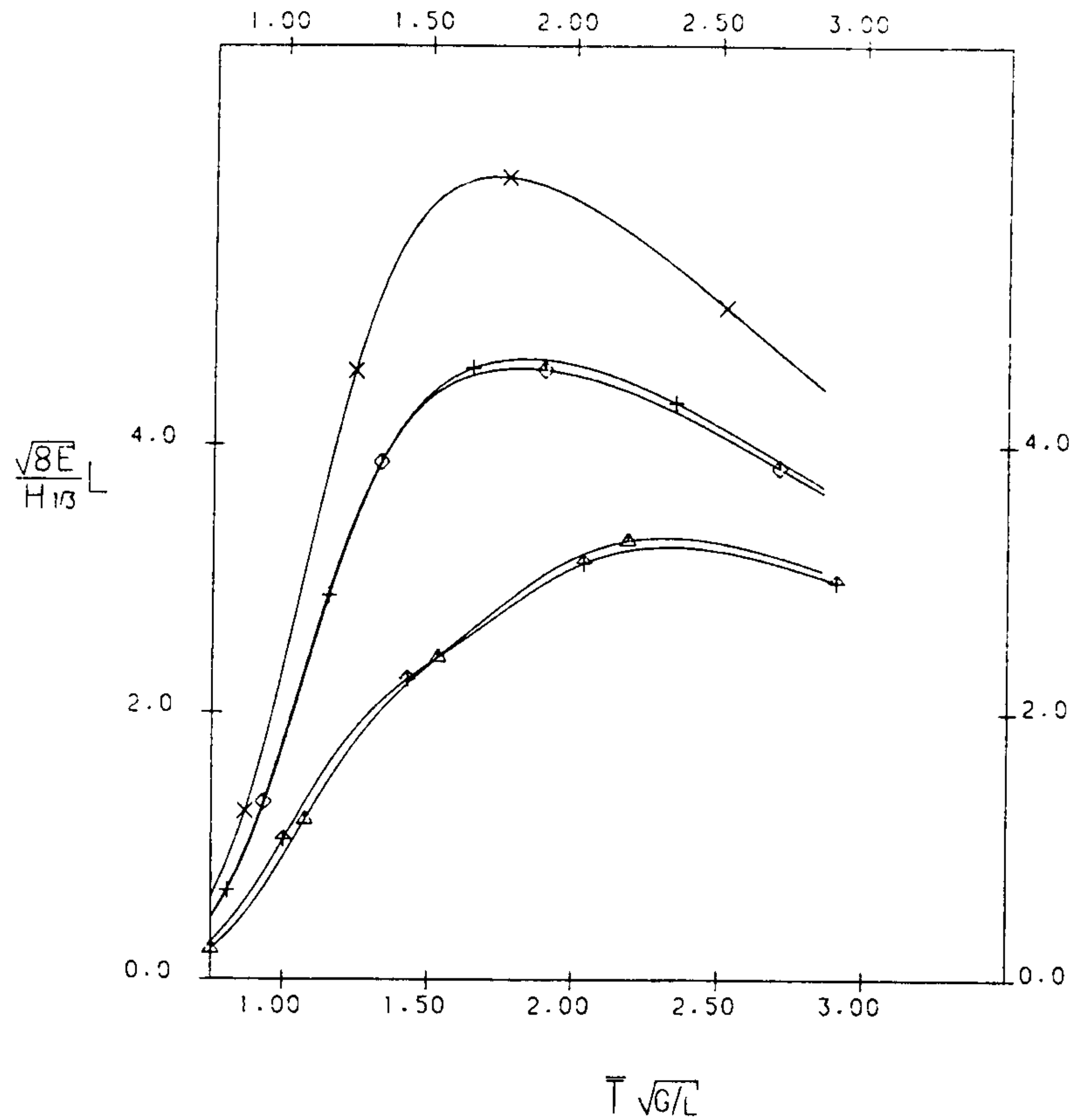


Figure 2.3.14 Sway acceleration response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

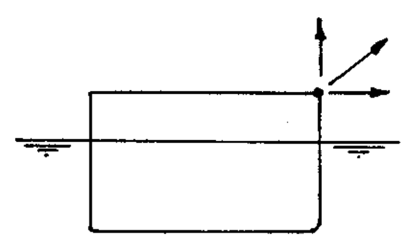
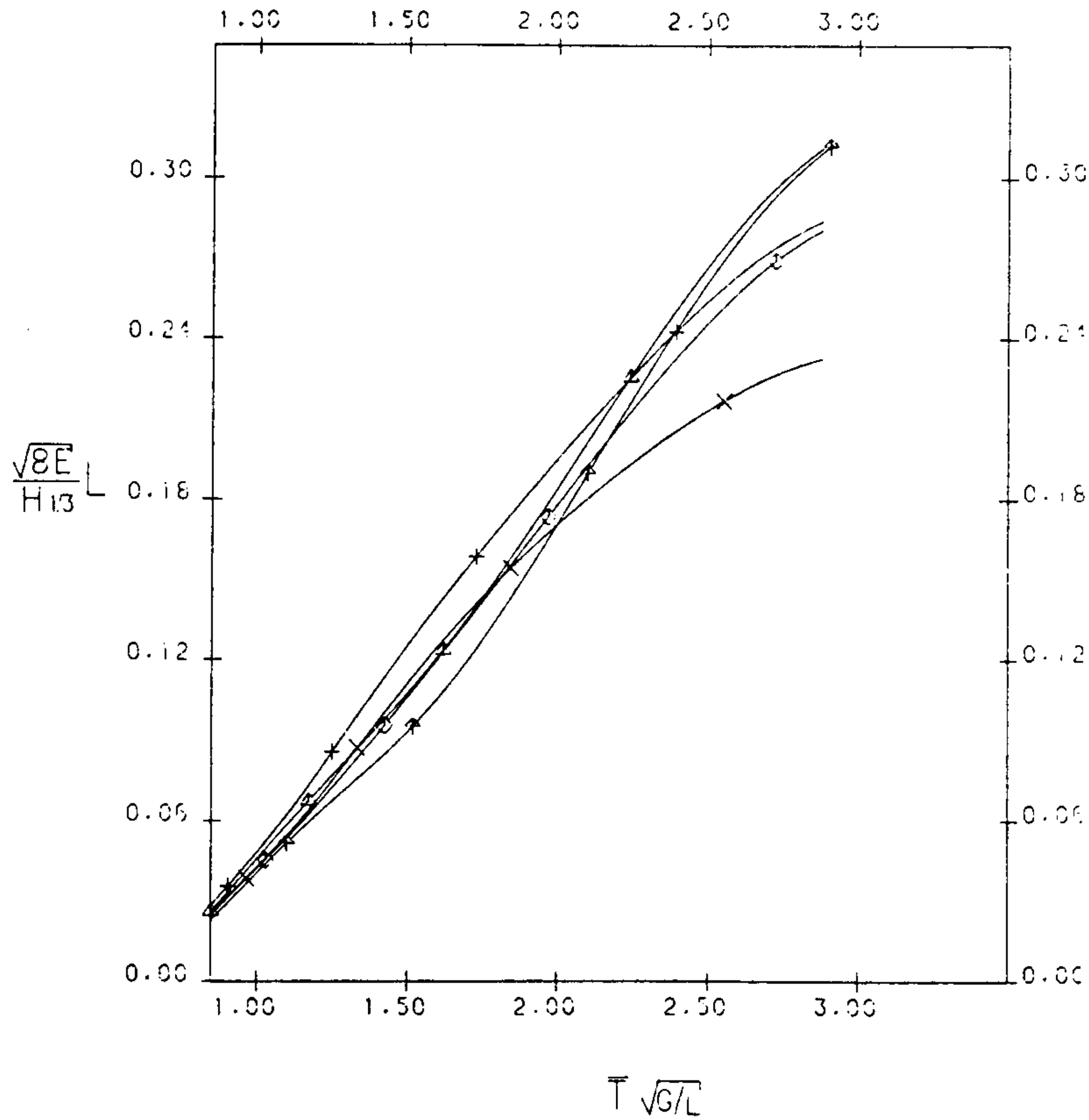


Figure 2.3.15 Heave acceleration response (loaded)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

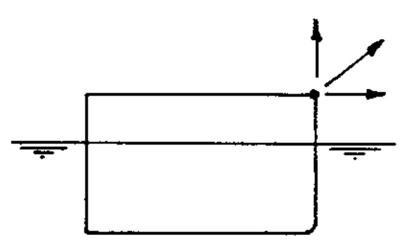
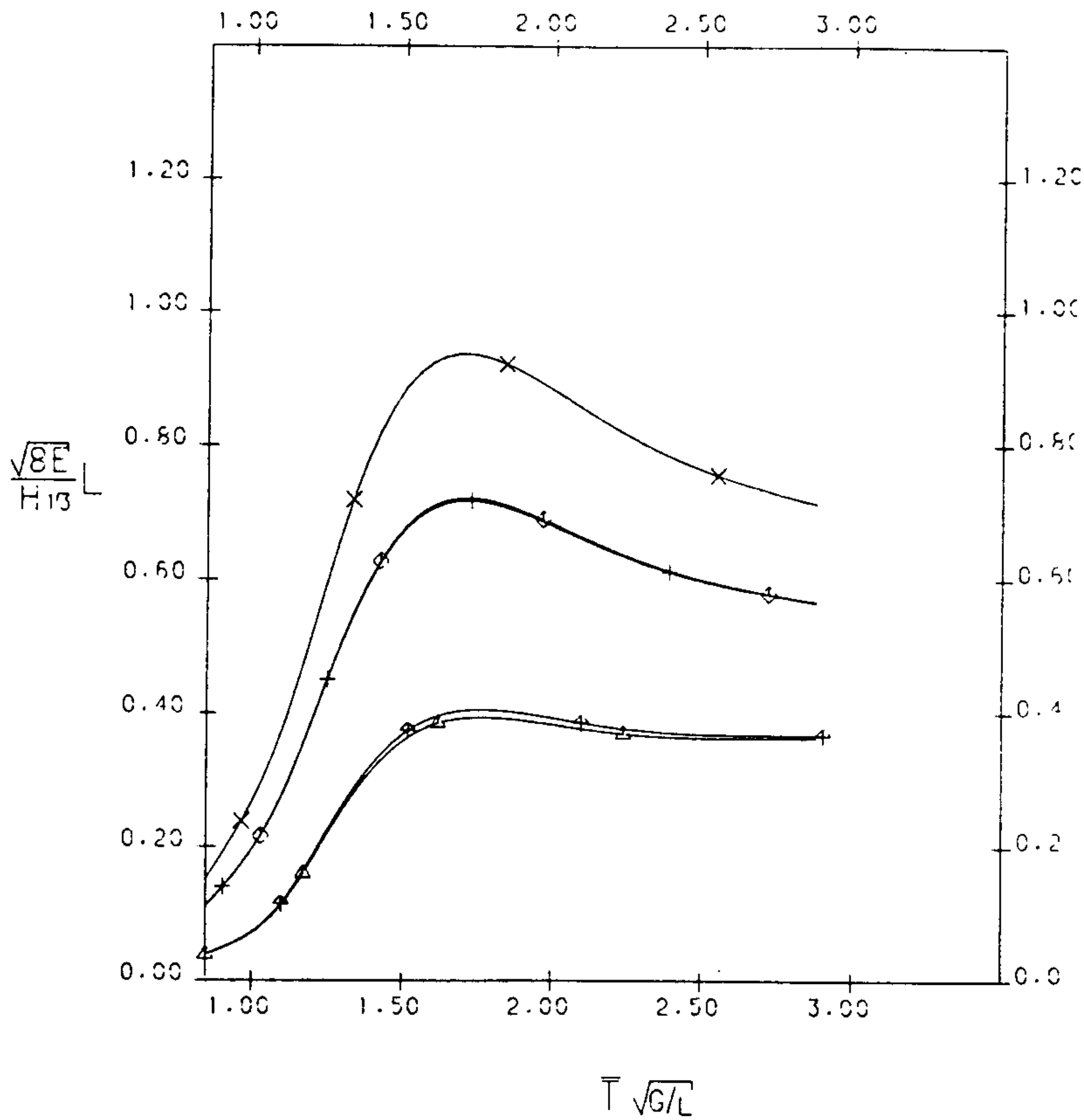


Figure 2.3.16 Surge displacement response (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- △ 000.00 (head seas)
- + 045.00 (quartering on bow)
- × 090.00 (beam seas)
- ◇ 135.00 (quartering on stern)
- ↑ 180.00 (stern seas)

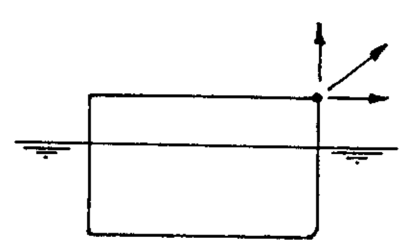
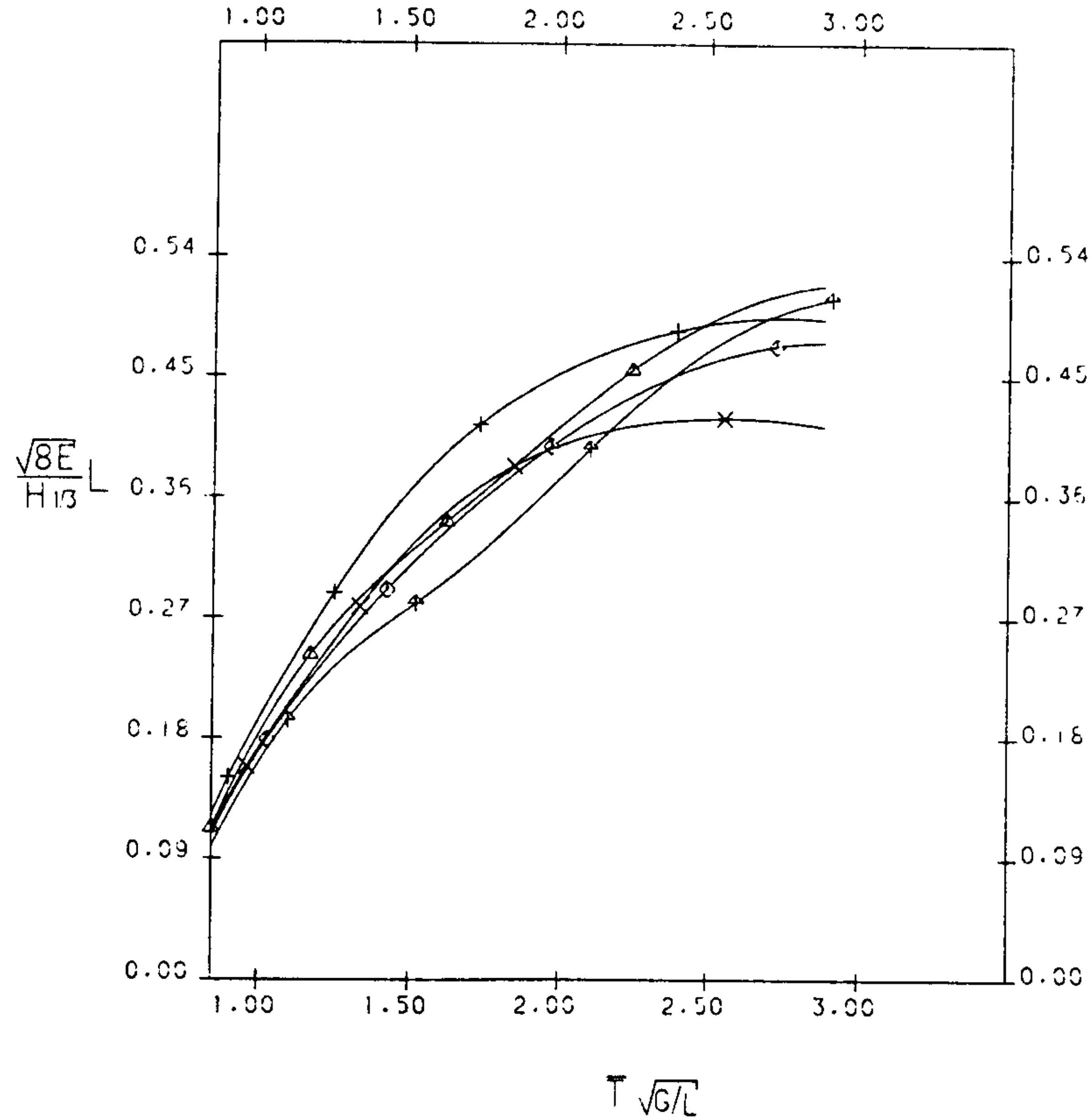


Figure 2.3.17 Sway displacement response (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

000.00 (head seas)

045.00 (quartering on bow)

090.00 (beam seas)

135.00 (quartering on stern)

180.00 (stern seas)

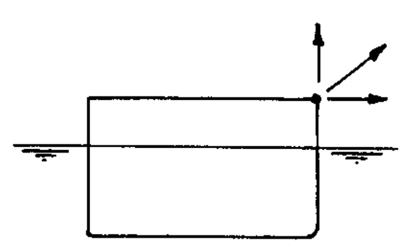
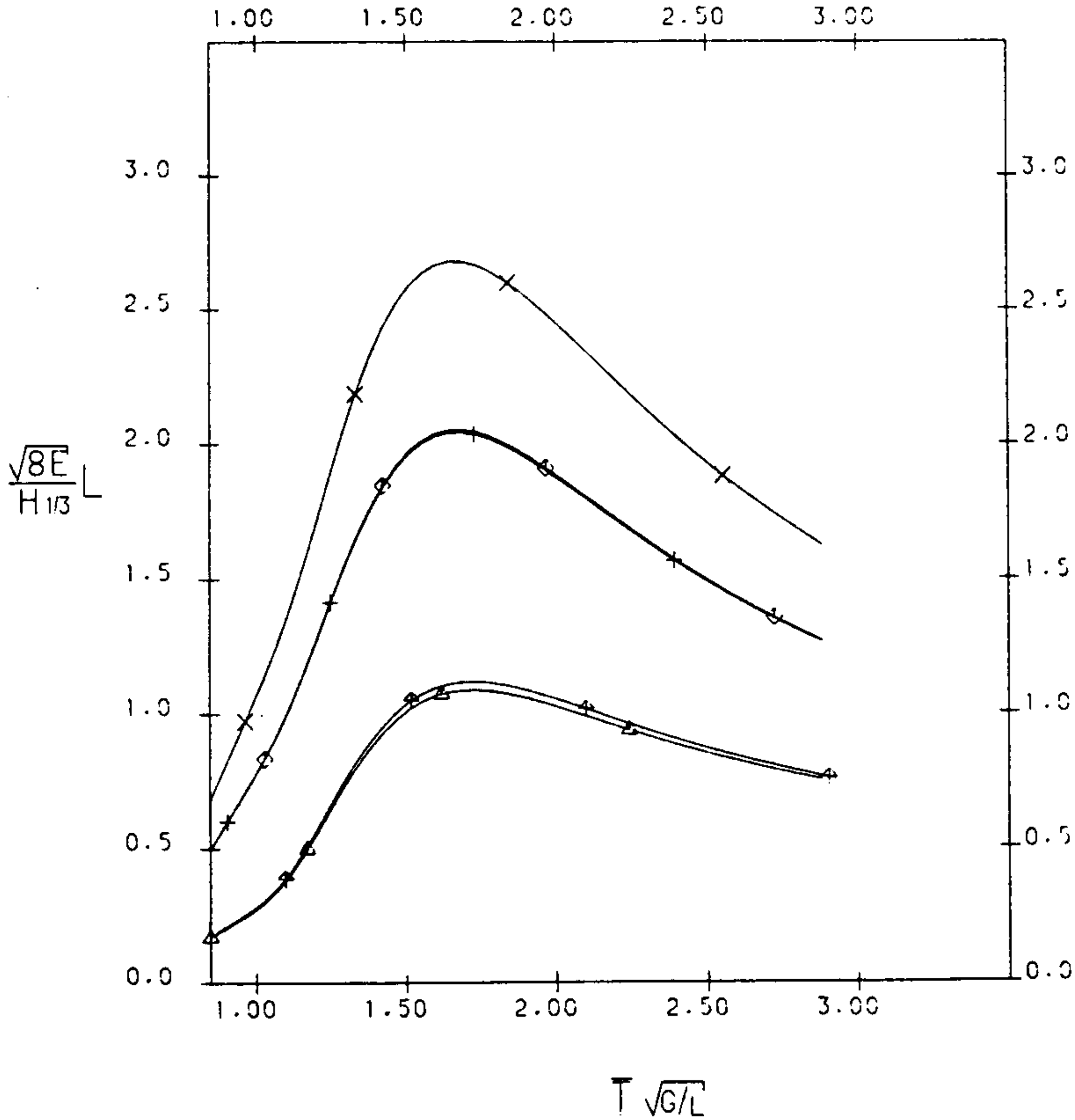


Figure 2.3.19 Surge velocity response (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

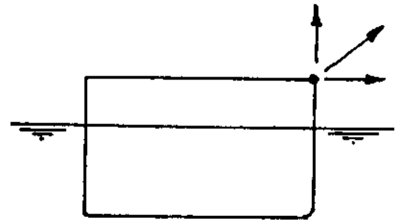
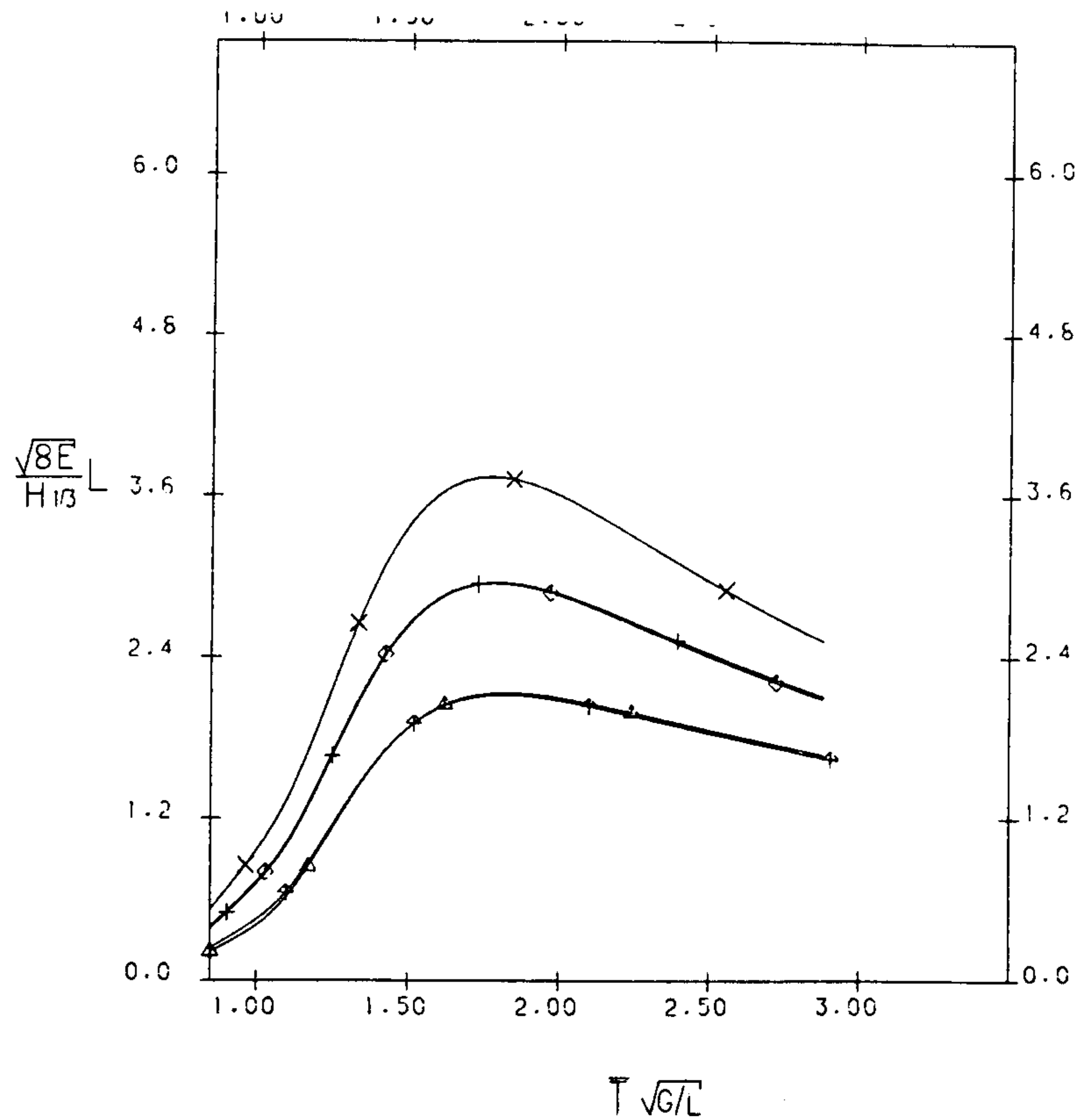


Figure 2.3.20 Sway velocity response (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

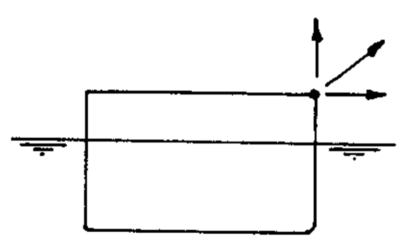
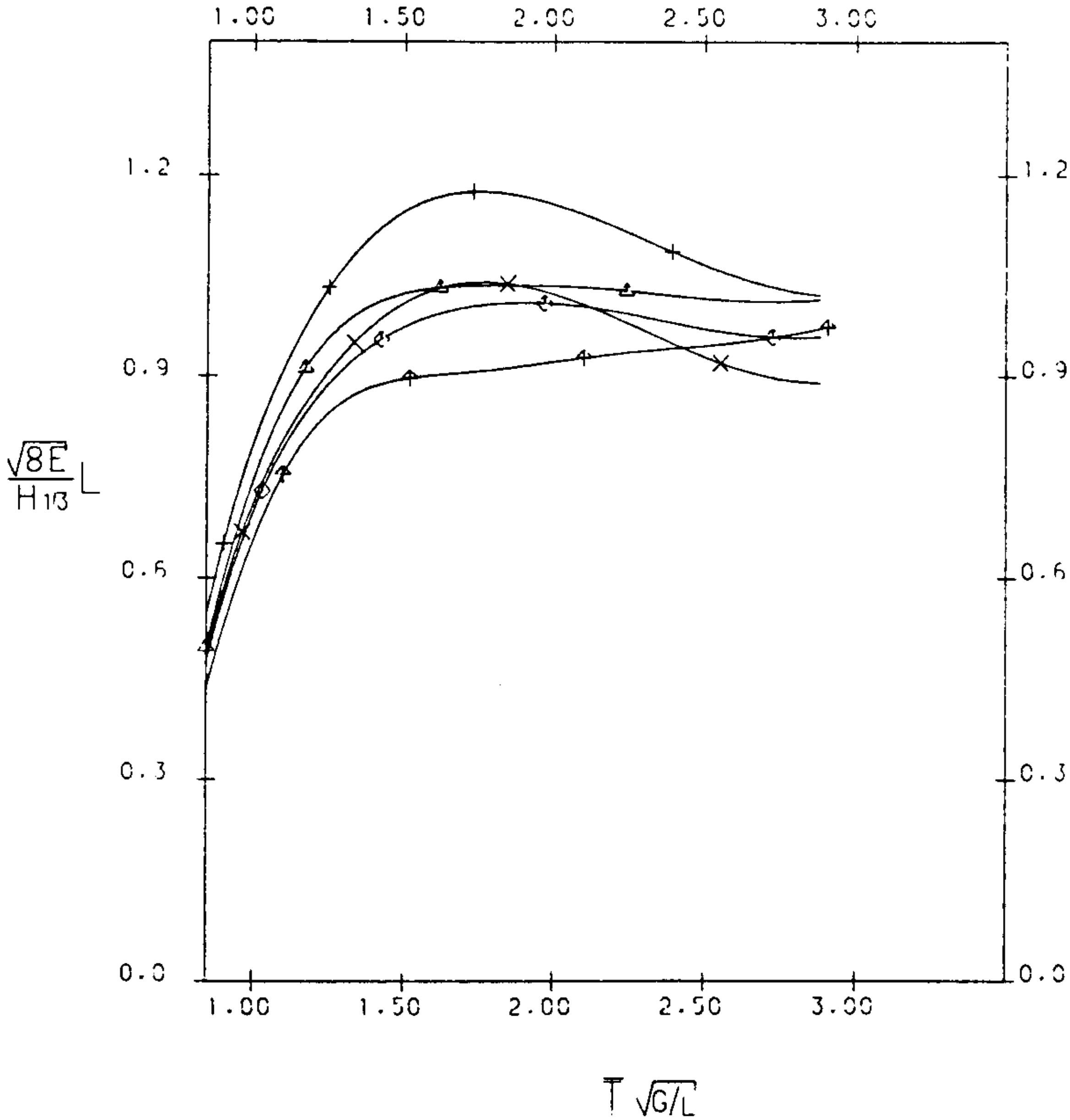


Figure 2.3.21 Heave velocity response (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

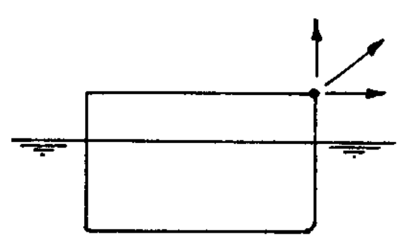
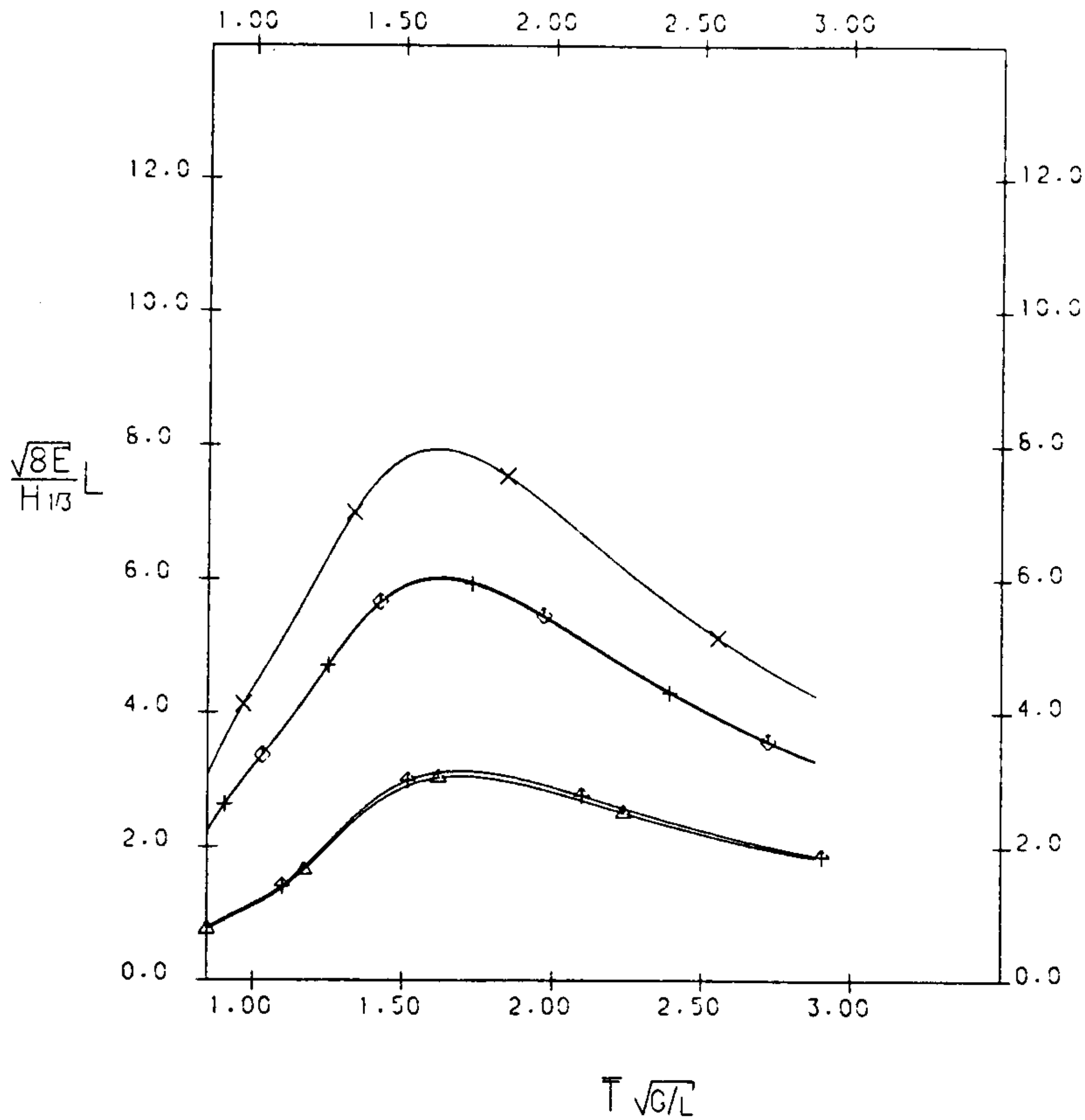


Figure 2.3.22 Surge acceleration response (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

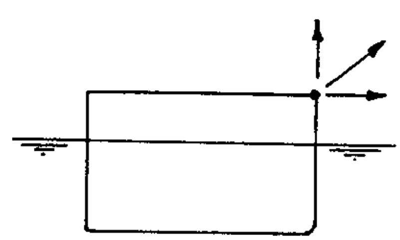
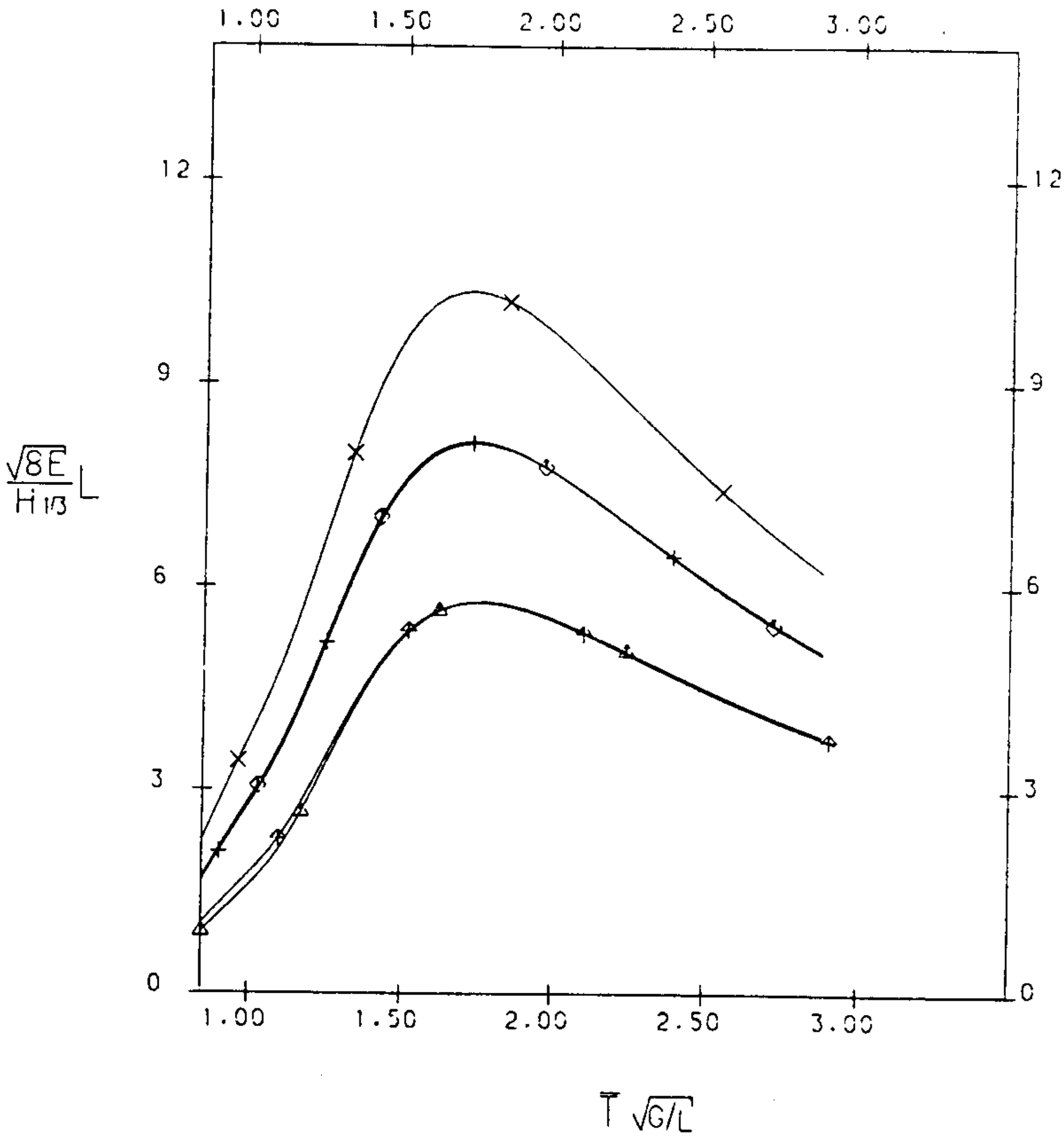


Figure 2.3.23 Sway acceleration response (ballast)



NOTES

All results are at zero Froude number (zero forward speed).

Results are given for the motions of a point at the deck corner amidships. Nomenclature is defined on pages 16-18.

LEGEND:

Heading Angle (wave direction relative to ship heading)

- 000.00 (head seas)
- 045.00 (quartering on bow)
- 090.00 (beam seas)
- 135.00 (quartering on stern)
- 180.00 (stern seas)

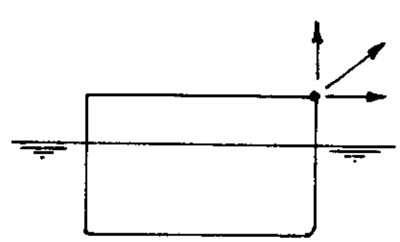


Figure 2.3.24 Heave acceleration response (ballast)

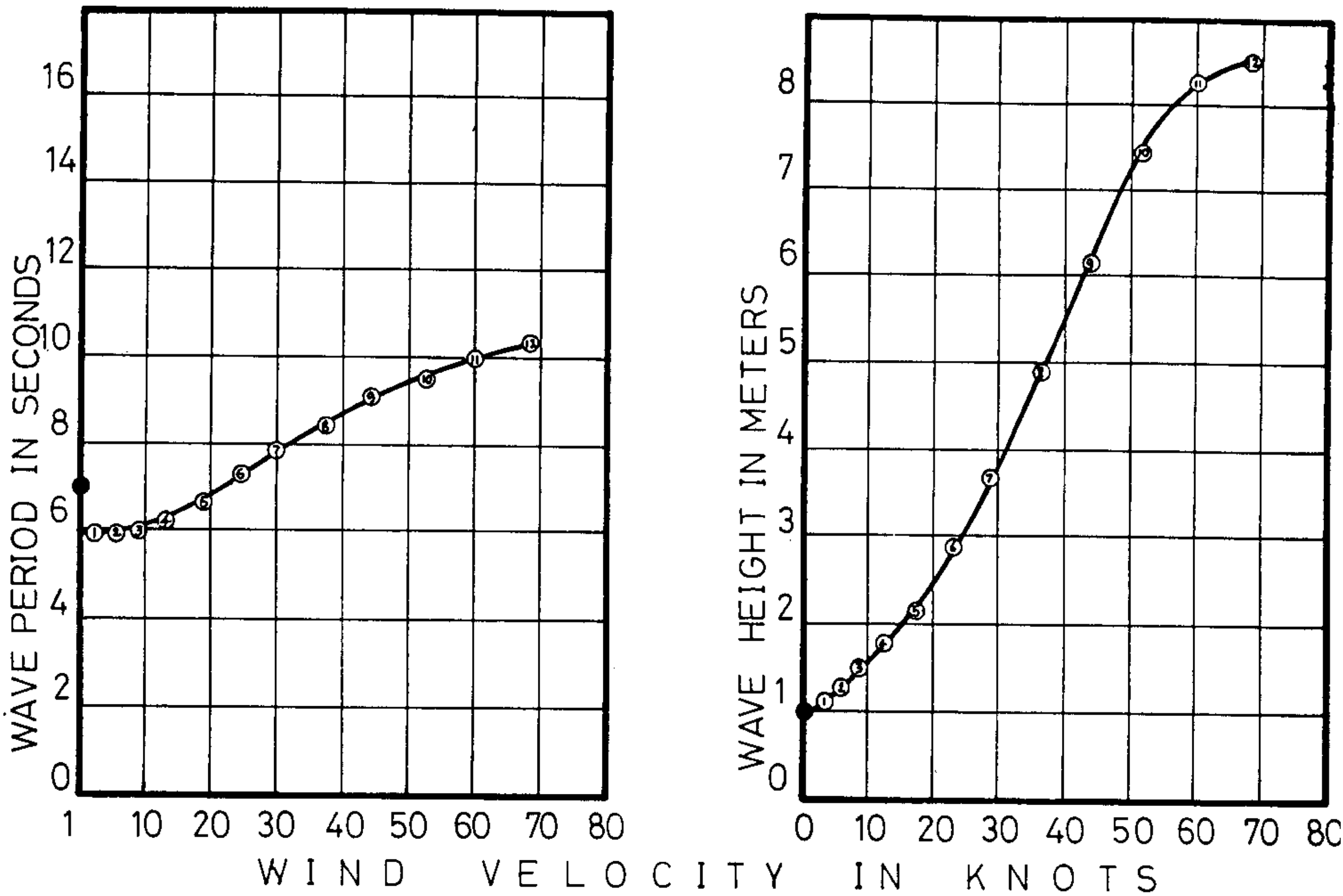


FIGURE 2.3.25 BEAUFORT SCALE & notes

Note:
The above curves show average height and period for waves observed in the North Atlantic, in relation to wind velocities. Beaufort scale numbers are shown in each circle. (Taken from SNAME T & R Bulletin No. 1-19, 1958) There is no fixed relationship between wave height, or period, and Beaufort Scale wind velocity. Depending upon length of fetch and duration of steady wind velocity, the sea may become fully developed. If the water is very deep, and if the empirical ITTC spectrum is used (International Towing Tank Convention) the significant wave height that that will be develpoed is between 2.5 and 3.5 meters. Use of other forms of spectra produces different theoretical significant wave heights, even in these ideal conditions. In general, fetch limitation and duration of a constant wind velocity, result in lower waves than these theoretical predictions, as evidenced by the observed values shown.

Beaufort Scale
(US Oceanographic Office)

wind force (Beaufort)	3	4	5	6	7	8	9	10
wind velocity (knots)	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55

2.4 DYNAMIC POSITIONING

Automatic positioning and maneuvering of the primary vessel will be achieved by active use of thrusters and the main propeller. The thrusters will be controlled automatically from a dynamic positioning system.

Examples of vessels recently equipped with DP systems are seven tankers used for offshore loading on the Statfjord Field in the North Sea with Mobil Oil as the operator. These vessel are provided with DP systems delivered by Kongsberg Albatross. The enhanced maneuverability with automatic station-keeping will be similar for this vessel. The DP feature will also enable stable operation during fire fighting and recovered oil transfer operations.

The general principles for automatic positioning and maneuvering are that thrusters and main propellers are controlled actively to counteract external forces resulting from wind, wave and sea current. Proper force must be provided to keep the vessel with a fixed heading and a fixed position or with a precise and defined movement. Therefore the thrusters and propellers must control the vessel's three axes'; longship (surge), beam (sway) and rotation (yaw). To control this automatically, the thrusters and propellers in turn need to be controlled from a computer which is the central part of the dynamic positioning system. Typically, positioning accuracy will be within 2 to 5 meters (mean position), dependent upon weather conditions.

The selected vessel is equipped at present with steam turbine propulsion equipment and a single large propeller. She is capable of slow steaming (even below 1 knot) for long periods of time, without modification. However, maneuverability is poor at such speeds, and the addition of two tunnel thrusters is required in order to improve this situation. One thruster unit should be fitted in the bow and one in the stern. Since the collector system needs to continuously move towards the surface oil slick, in order to maximize oil depth at the booms and skimmers, the ship will invariably have a relative velocity through the water. A tunnel thruster at the bow and a tunnel thruster at the stern, coupled with normal rudder and aft propulsion will enable close control over the vessel's surge, sway and yaw motion.

2.4.1 Vessel Requirement

The total system involved for dynamic positioning is described in this section.

Two thrusters must be fitted, one located in the bow, one located in the stern. These units will be of the tunnel type. Force variation is achieved by controlling propeller pitch, with propeller running at constant RPM in the bow. In the stern a fixed pitch propeller is installed. The stern thruster is driven by the ship's electric power and should be mounted as close to the stern as possible. The bow thruster has a separate diesel power unit.

Forces to be resisted by the dp system are wind, waves and current. The aft superstructure of the vessel causes a yawing moment in all conditions of wind, except for pure head and pure stern winds. Yawing moments also exist to a lesser extent because of wave and current forces.

The dp system does not attempt to counteract the so called first order wave oscillatory forces (causing short period oscillatory motions of surge, sway, yaw, roll, pitch, heave. See Section 2.3). However, the slowly vary components of the so called second order wave drift forces are resisted. As with current forces, wave drift forces are a function only of the underwater shape of the vessel and increase with increasing draft.

For oil collection operations, the dp system is sized to at least cope with station keeping in weather conditions up to Beaufort 5:

Significant wave height (Hs):	2.5m (8.2 feet)
Wind speed:	20 knots (approx. 10 m/s)
Wave Period (T_Z):	7.0 seconds

The design current velocity is for station keeping during collection operations is a combination of wind driven surface current, V_{wind}, and a tidal current V_{tide}.

$$V_{wind} = 0.02 \text{ (wind speed)}$$
$$= 0.4 \text{ knots}$$
$$V_{tide} = \text{is taken at 1 knot}$$

Max current velocity = 1.4 knots

(Note that this is in excess of the maximum optimum velocity for collection boom operation, by 0.4 knots).

2.4.2 Current Loads

During collection operations, the maximum current load with which the thrusters need to cope is not a beam current, although a beam current results in the greatest demand on the dp system. However, for the purpose of adequate maneuverability, a 30^{o} angle to the current is considered for thruster sizing:

Lateral current force, F_c, is calculated from:

$$Fc := \frac{1}{2} \cdot Cdu \cdot ew \cdot A \cdot (v \cdot \cos(60))^2$$

where:

Fc = lateral current force
Cdu = drag coefficient, associated with tanker underbody, for a given direction
ew = mass density of sea water
A = area of tanker exposed to current (approximately length x draft x 0.9)

NOTE:
This is a simplified calculation used for initial sizing. For maximum draft conditions this results in :

Fc = 24 tons force.

This must be resisted by a combination of both bow and stern thruster.

2.4.3 **Wind Loads**

In most conditions the wind will be in the general direction as that of the travel of the oil and similar logic to that applied above for the current is used. However, to accommodate wind shifts, an angle of attack of 40^0 is considered.

Lateral wind force, F_w, is calculated from:

$$Fw := \frac{1}{2} \cdot Cda \cdot ea \cdot A1 \cdot (u \cos(50))^2$$

where:

Fw = lateral wind force
Cda = drag coefficient, associated with above water parts of tanker underbody
ew = mass density of sea water
u = wind velocity
A1 = area of tanker exposed to wind

NOTE:
This is a simplified calculation used for initial sizing.

Fw = 5 tons force

2.4.4 Wave Loads

Wave drift forces will come from both the wind driven waves and any swell that may be present. In this case the swell component may come from any direction and beam seas is the worst design case. Waves driven by the wind will normally be from ahead, in a collection operation, but by similar argument to that applied for the current, a 30° angle is considered.

Drift forces are dependent upon the vessel geometry and the wave/swell spectral shapes. From internal VERITEC reports, and from API RP2P, the magnitude of the drift forces to be resisted by the thrusters has been derived as shown below.

$$Fmdy := Cmdh \cdot \left[B^2 \, L \right] \cdot Hs^2$$

where:
Fmdy = mean drift force due to beam seas
Cmdh = mean drift force coefficient, from figure 3, API, RP2P
B = hull beam
L = length at water line
Hs = design wave height (in this case 8.2 feet)

From API, RP2P
Cmdh = 0.8E-4 lb/ft^5 in beam swell
Cmdh = 0.7E-4 lb/ft^5 in beam wind waves

With significant wave height of 8.2 feet, or swell height 8.2 feet, this results in a thruster force requirement of 24 tons apportioned between forward or aft stations, in order to resist beam seas.

Head seas, either swell or wind waves, result in mean drift forces of only two tons or less.

With 8.2 feet beam swell and 8.2 feet significant head seas at 30°, the thruster requirement becomes 34 tons.

2.4.5 Summary of the thruster requirements:

Current force	=	24 tons
Wind force	=	5 tons
Wave drift force	=	34 tons
TOTAL		63 tons

From the foregoing calculation of forces, it can be shown that a combined effective horse power of around 1,500 is required to maintain positions of the tanker against the worst combination of forces during collection operations. However, the need for rapid response to environmental disturbances and in emergency conditions dictates that considerably more power than this should be made available. The possibility of operating the collection tanker in crowded oil production fields also requires good vessel maneuverability. Furthermore, the collection tanker may have to position itself with the beam facing the environment to protect the two boats during the oil boom deployment and recovery operation. Therefore, the minimum thruster size required is selected as:

Bow = 2000 hp
Stern= 1500 hp

The excess 500 hp capacity for the bow thruster is necessary to improve foreward steering capability and to resist the yawing moment caused by the imbalance of the hull superstructure and underwater geometry.

With this power available, adequate maneuverability for the routine collection operation is available; additionally there is a sizable power availability to cope with emergency conditions.

Experience has shown that thruster tunnel diameters should be between 2.4 - 2.7m (7.9 - 8.9 feet).

2.4.6 Dynamic Positioning Control System

An operator console with built-it computers and dedicated system software is provided within an operators' panel with joystick and heading controller for manual control. The operator's console will typically be mounted in the helmsman section of the bridge.

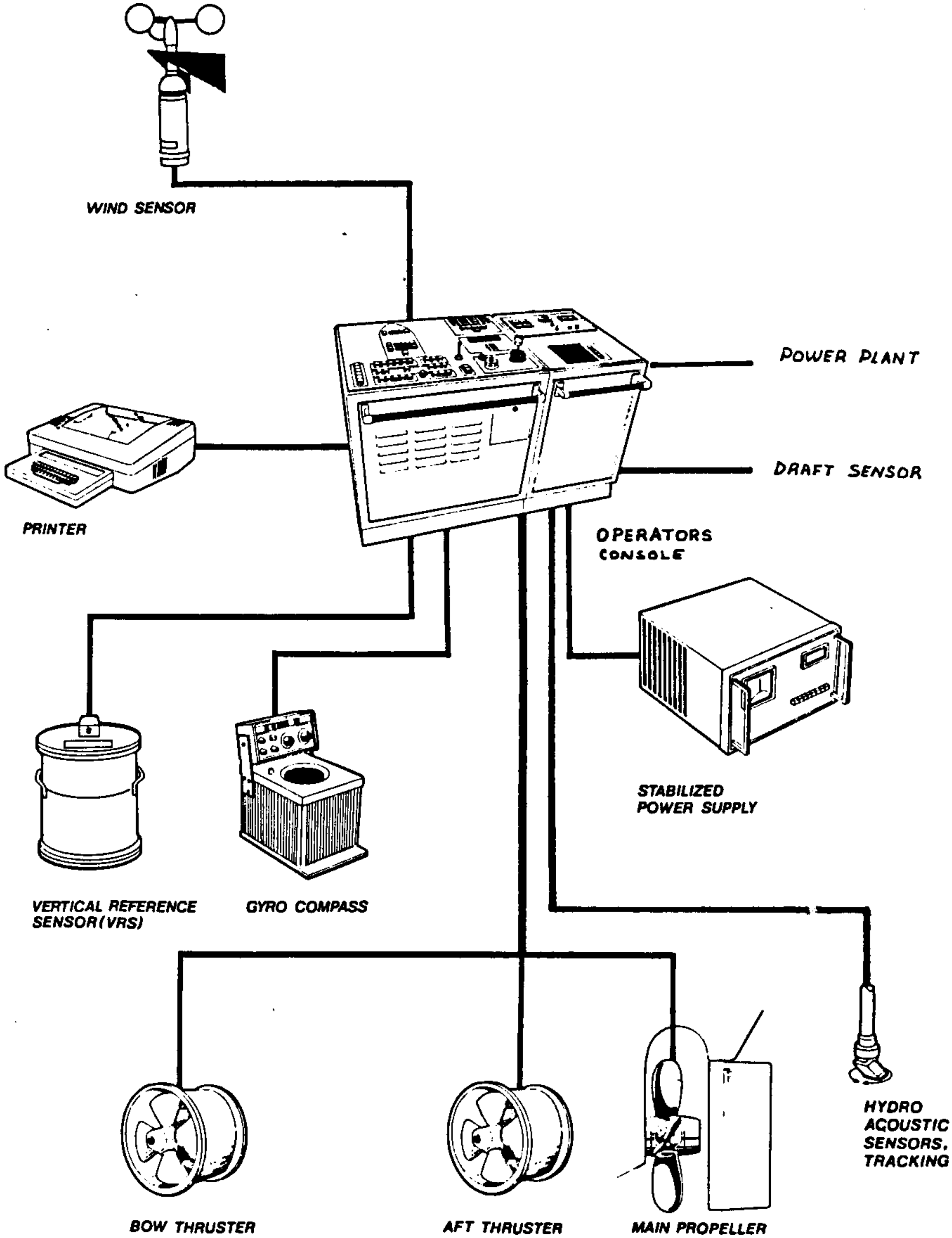
The system will be connected to sensors, peripherals and position indicators which are integral parts of the DP system and as outlined and illustrated in Figure 2.4.1. Additionally it will be connected to thrusters, main engine, switchboard and an external draft sensor.

An alarm is given for the following faults:

- Power failure of remote system
- Power failure of alarm system
- Low level in lube oil tank
- Low level in oil pressure (if forced lube oil system)
- Low level in hydraulic supply tank
- Low pressure in hydraulic system
- High level in bilge well

Additionally, on the bridge, indication is provided for:

- Overload of prime mover and servo unit if automatic load limitation is not provided.
- Available power to alarm and reduce power consumed by thrusters to eliminate overload and possibly blackout.



Typical D.P. System

Figure 2.4.1

- Propeller pitch for the c.p. propeller.
- Direction of rotation and rpm for the fixed propeller.
- Power failure of alarm system.
- Failure of thruster plant (common alarm)

It will also be possible to stop the thrusters from the bridge by a system independent from the remote control system.

Sufficient power for the aft thruster at maximum capacity exists in the ship already.

The main propeller is RPM controllable for ahead and reverse motion. The steam turbine systems will be modified to accept electrical input for rpm control and with feedback to the DP system.

A function for automatic limit of pitch or RPM is integrated to prevent generator overload. Manual or semiautomatic (i.e., auto control of one or more of vessel axis) control of vessel position and heading can also be accomplished from integral 3-axis joystick.

Peripherals; vertical reference senor (VRS) for roll and pitch, wind sensor for wind speed and direction, line power stabilizer with distribution and interface to ship gyrocompass.

Hydroacoustic Position Reference System with transceiver and display/control unit, tracking transducer with hull unit for extension under the hull, beam and motor control unit, interface to VRS, gyrocompass and DP computer, gate valve, mounting flange and transponders.

The hydroacoustic system works on the super-short baseline principle, which means it can work with only one transponder on the seabed. The maximum total range (slant range) is approximately 2000-3000 meters. To cover a larger area, more transponders can be dropped to the seabed. Transponders will also be mounted on the boom towing vessels and the graphics display will continuously show the locations of these vessels.

The thruster tunnels are shown on the general arrangement drawing.

The alternative of a satellite system appears attractive and could certainly be made to work. However, seabed transponder systems have already been engineered and are reliable. Hence, it is considered more advantageous and certainly more cost effective to use such seabed systems.

2.5 SHIP OPERATIONS

In this section a description is given of an oil collection operation with target characteristics defined by the MMS as follows:

Time of Year	:Winter
Location	:Mid Atlantic OCS, 100 miles offshore
Oil Blowout Rate	:30,000 barrels/day
Oil Type	:Medium weight crude
Gas Blowout Rate	:765,000 cubic meters per day
Gas Type	:Natural gas, no sour gas
Duration of Operation	:150 days until relief well is completed

Note that the logistics of operation in the above Atlantic conditions are more difficult than for similar operations in target areas off the West Coast. Larger support vessels are needed and efficiency will be reduced because of environmental conditions more frequently exceeding those limiting operations (see Section 2.13, Operability Study).

As noted in Section 2.1, having received the call for assistance, the primary vessel may first have to offload her cargo or she may proceed directly to the blowout location. In the case of the primary vessel being engaged in West Coast trading, the probable minimum time to reach the blowout location would be 13 days, depending upon precise vessel location at the time and any delay through the Panama Canal. A probable maximum time would be 21 days, if she first had to discharge cargo. This indicates that up to 630,000 barrels of oil could be spilled before the primary vessel reached the blowout location.

It is imperative that the logistics of oil collection management are established for any project at the outset. The duties and responsibilities of the captain of the primary collection vessel must be clearly defined before he reaches the blowout location. It is recommended that he is given full responsibility for directing offshore collection operations and that he reports to the person appointed overall Director of Operations or On-Scene Coordinator. In this role the collection vessel captain will then direct all other vessels in the area. He will also be given air support. A helicopter should be stationed on his vessel when the operation commences. He will direct offloading as well as oil collection operations. He will decide when to retrieve and/or to replace booms and skimmer equipment. He will decide when gas conditions are hazardous to his vessel and will give advice to the captains of the boom towing vessels.

There should be no attempt on the part of the primary vessel to attempt to collect old highly emulsified oil. Instead, the operation should concentrate upon collection of "new" oil. Aerial reconnaissance will be needed for maximum efficiency in order to direct the primary vessel into a location downstream of the blowout.

A liaison point downstream and to one side of the surface oil at a distance of around one mile from the blowout must be established. At this location boom deployment and hookup to boom towing vessels will take place. Limiting conditions for this operation will be Beaufort 5 as noted in Section 2.3. At least one of the specially trained crew from the collection vessel will be transferred to each of the boom towing vessels to help direct and assist with boom deployment.

2.5.1 Selection of Boom Towing Vessels

The two boom towing vessels, plus one additional standby/supply vessel should be 2000 - 4000 HP tug/supply class vessels in the range of 140-180 feet long. They also need to be highly maneuverable. At a minimum they should be twin screw with a bow thruster. They should be dispatched from a nearby port and cannot be expected to be experienced in oil spill collection. These vessels should have a towing winch and deck winches, and a clear aft deck area. They should be classed for full ocean towing service, and should also have a clear after rail.

The selection of suitable boom towing vessels is important, especially as concerns their maneuverability. Like the tanker, they must hold position and slowly move (1 knot) for the 150 day target duration of the operation. Controllable pitch propellers are ideal for this, but not frequently found in this class of vessel. A bow thruster is a necessity. At least one operator's experience (Tidewater Marine) at the lxtoc blowout, shows that continuous clutching of fixed propellers, with one or two engines running dead slow, is possible for many weeks without maintenance problems.

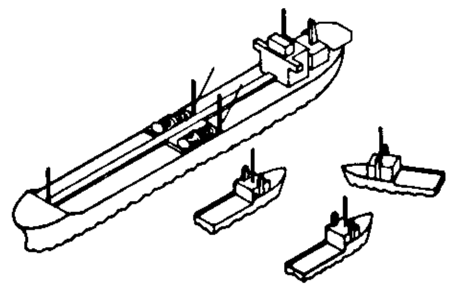
It is also desirable that these vessels have closed cooling systems, to avoid possible fouling by the oily water that may occur with raw water exchangers (common on vessels with 6000 HP or more). The horse power of these vessels is not a significant criterion for their selection, since the boom towing forces are small (of the order 5 tons) but their seaworthiness is of importance, especially if the collection operation is to take place in a harsh environment area, far from shore (e.g., north Atlantic).

The endurance capability of these vessels should be around 40 days minimum and they should be crewed by at least 9, to allow for 24 hour operation. The more modern vessels in this class are equipped with monitors, dedicated pumps and foam systems to provide for an oil field firefighting capability. This capability is important and should be selected for this operation.

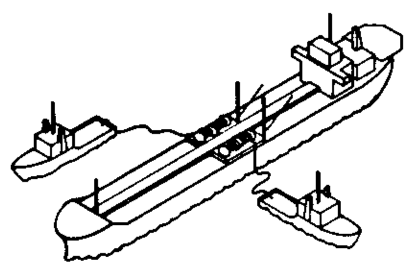
Inquiries indicate that there are about 100 vessels in U.S. waters suitable for the boom towing part of the collection operation.

2.5.2 Deployment of Equipment

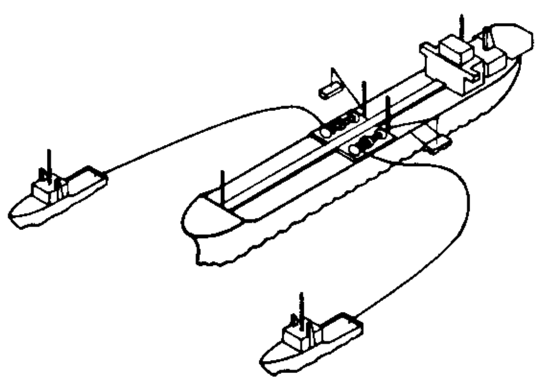
The overall liaison and deployment scenario is illustrated in figure 2.5.1. Having reached the liaison point, the skippers of all three smaller vessels will go onboard the primary oil spill collection vessel for a briefing with the primary vessel skipper. Other key personnel who should be at this meeting will be oil company representatives, drilling contractor representatives (for drilling the relief well), key crew members from the primary vessel, the overall Director of Operations (OCS), and the helicopter pilot.



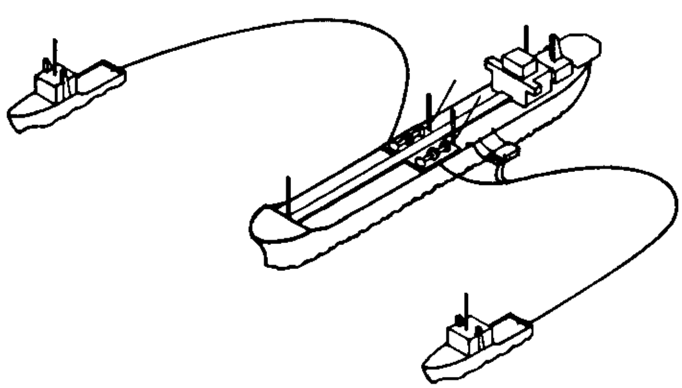
① SHIP AND SERVICE VESSELS ARRIVE AT BLOWOUT



② BOOM IS DEPLOYED FROM STORAGE REELS BY SERVICE VESSELS



③ COLLECTOR/LIFT BARGES ARE LAUNCHED FROM SHIP, BOOM COLLECTION HOSES ARE ATTACHED



④ OIL COLLECTION COMMENCES

Figure 2.5.1
LIASON AND DEPLOYMENT SCENARIO

The plan for boom deployment and operation will be carefully explained. Boom strength limitations as well as performance limitations will be discussed in order to avoid premature boom failure. Ignition and re-ignition of the blowing gas will be planned. Refueling procedures, etc., will be planned and rehearsed where possible.

Boom deployment will then commence with at least one trained crewmember from the collection vessel being transferred to each of the two vessels selected from boom towing. Deployment procedures for the Offshore Devices, Inc., "Skimming Barrier", are presented in this document. The deployment of other types of booms is also feasible.

In order to achieve optimum efficiency particularly in weather conditions near limits of operation, a lift barge with pump and hot water and steam injection capabilities be provided at either side of the primary collection vessel, behind the booms. The weir pumps at the apex of the booms will discharge to these barges via floating hoses. A surge tank and three hydraulic double acting diaphragm pumps within each barge will enable oil collected at the sea surface level to be pumped up to the processing equipment via through hull connections in the ship's side. Hot water or steam produced on the primary vessel, can also be injected into the collected oil/water mixture, at these barges in order to help break emulsions, particularly in the cold conditions of the North Atlantic winter. The operation of the floating equipment is more fully described in Section 2.8. The lift barges have been designed to have low motion characteristics. The design is such that the water line lies near the geometrical discontinuity of the hull (top and keels).

The large water plane area provides good stability to the barges which is further increased by their deep keels. The large changes in water plane area as waves pass the barges induce a highly nonlinear apparent stiffness. Thus the natural period appears to vary as wave steepness and height increase. The overall result is that the motions of the barges are relatively small and the barges provide stable work platforms and the opportunity to start oil/water separaton at sea level.

Each lift barge is also provided with a hydraulic line from the ship to provide power for the diaphragm pumps. The use of centrifugal pumps is avoided, since their action tends to increase emulsification of the oil. The diaphragm pumps lift the collected oil water mixture to the ship process equipment, via flexible hoses, connected to the ship side. The lifting is assisted by a vacuum induced by the ship's equipment in the process area.

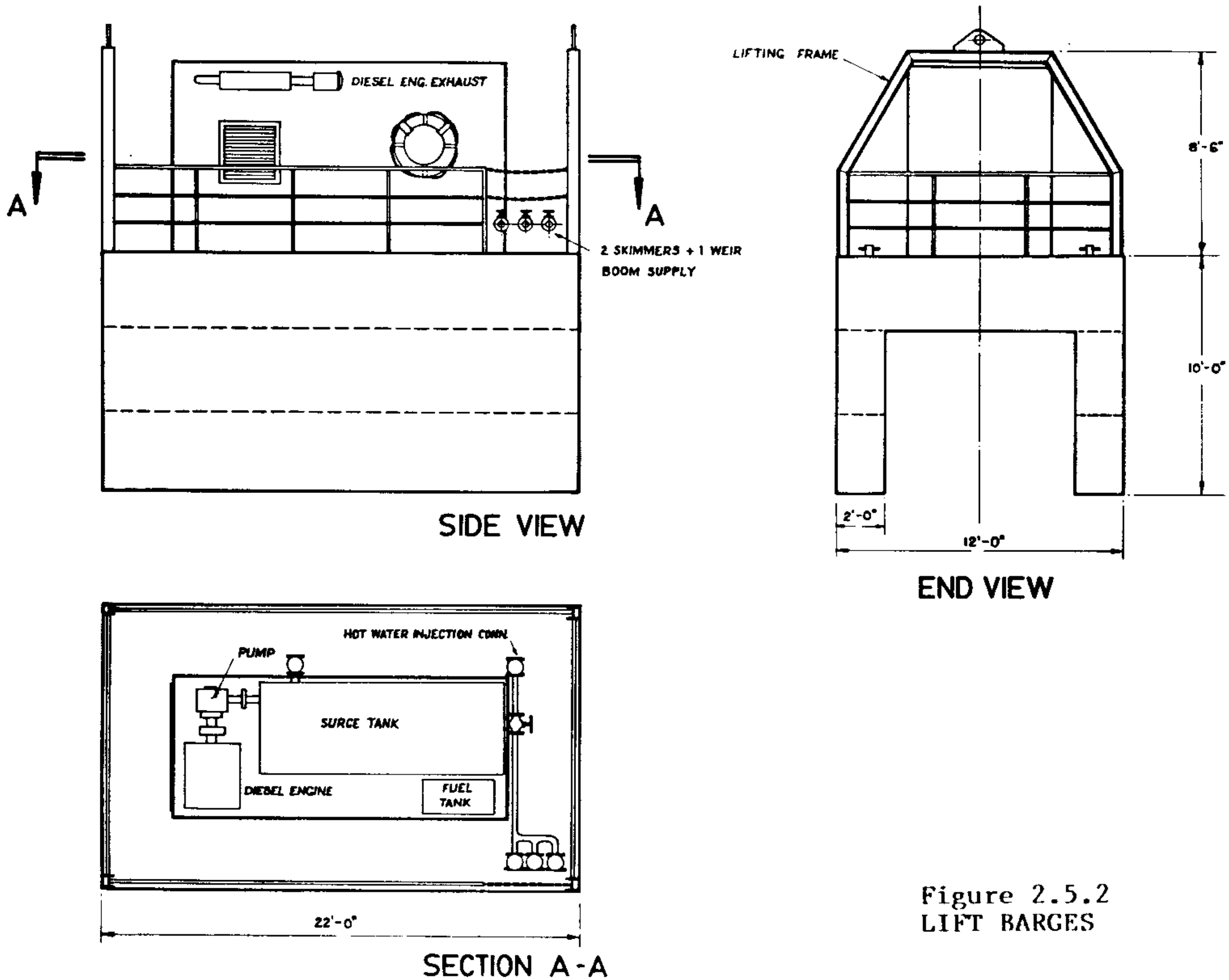


Figure 2.5.2
LIFT BARGES

2.5.3 Dynamic Positioning in Operation

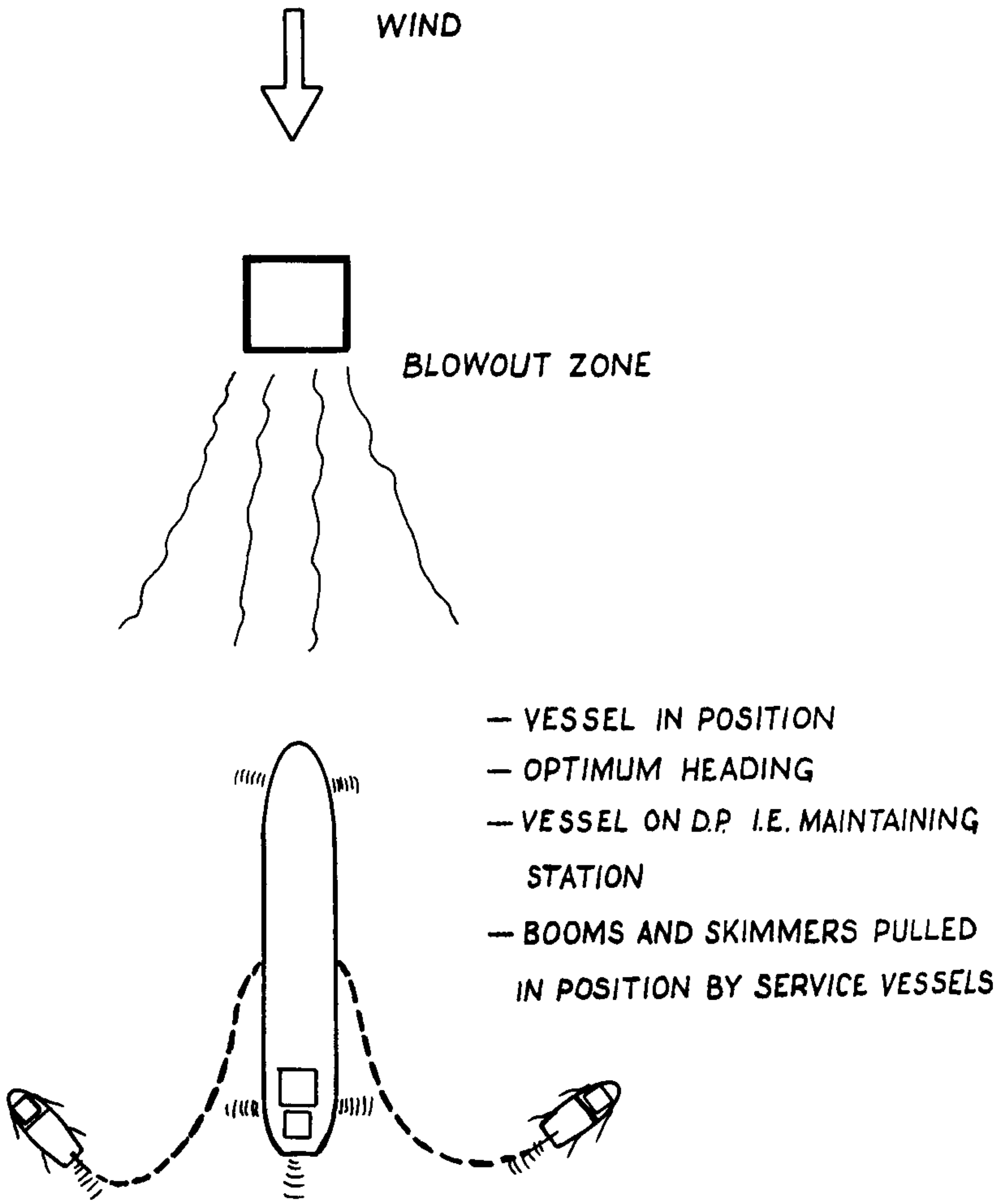
When the vessel is at site of operation one or more transponders will be lowered to the seabed. Typically each transponder is tied to a buoy (or will have a feature for automatic release from a sea bed anchor) for recovery after the completed mission.

As described previously in this section, the DP system will maintain the vessel stationary and typically will be commanded for "Optimum Heading", i.e., it will automatically turn so that total environmental forces acting on the hull and superstructure are minimized, thereby reducing machinery wear and fuel consumption, while maintaining a pre-set path for the vessel.

In conditions up to Beaufort 5, the booms will be pulled into proper position by the two boom towing vessels, one on either side of the vessel. The additional skimmers will be deployed, if necessary, and maneuvered by the ship's cranes.

In weather conditions exceeding the operational limits for the overall system, the collection vessel will move out of the oil slick and turn perpendicular to the wind and waves, or at some angle to provide a sheltered lee, while not becoming subject to excessive roll motion. It will use available capacity from the thrusters to maintain heading and position with priority on heading when thrust is insufficient to hold position. This will provide a lee for boom retrieval and deployment.

Figure 2.5.3
USE OF THRUSTERS IN NORMAL OPERATIONS



The booms and skimmers will then be handled, one at a time, on the leeward side of the vessel. During deployment, with one boom in position, the DP system will be given the command to turn, and turning rate. The tug with the boom already out will have to maneuver accordingly until the turning is completed. Now the second tug will start to position the other boom. Once both booms with skimmers are in position, a new heading command to put bow against the oil spill is given to the DP system with the tugs to follow. This is illustrated in figure 2.5.4.

When the overall system is set up and ready for operation, the DP system will be commanded for fixed position or a forward motion along a predefined track. The DP operator (or Captain) will define the proper speed and the end point of motion. For more complex movements he may also define a motion pattern with multiple turning points underway. The tug skippers will stay in close communication with the DP operator of the primary collection vessel. They will steer the tugs at approximately the same speed and motion pattern to maximize capture of oil slick.

A typical DP system is illustrated in figure 2.4.1 Provision and planning for re-supply of fuel (for all vessels and the helicopters), water, food, and chemicals must be made.

A tanker of 80,000 to 100,000 dwt is typically equipped with 22,000 hp main engine. During oil recovery operation, the tanker maneuvers at very slow speed

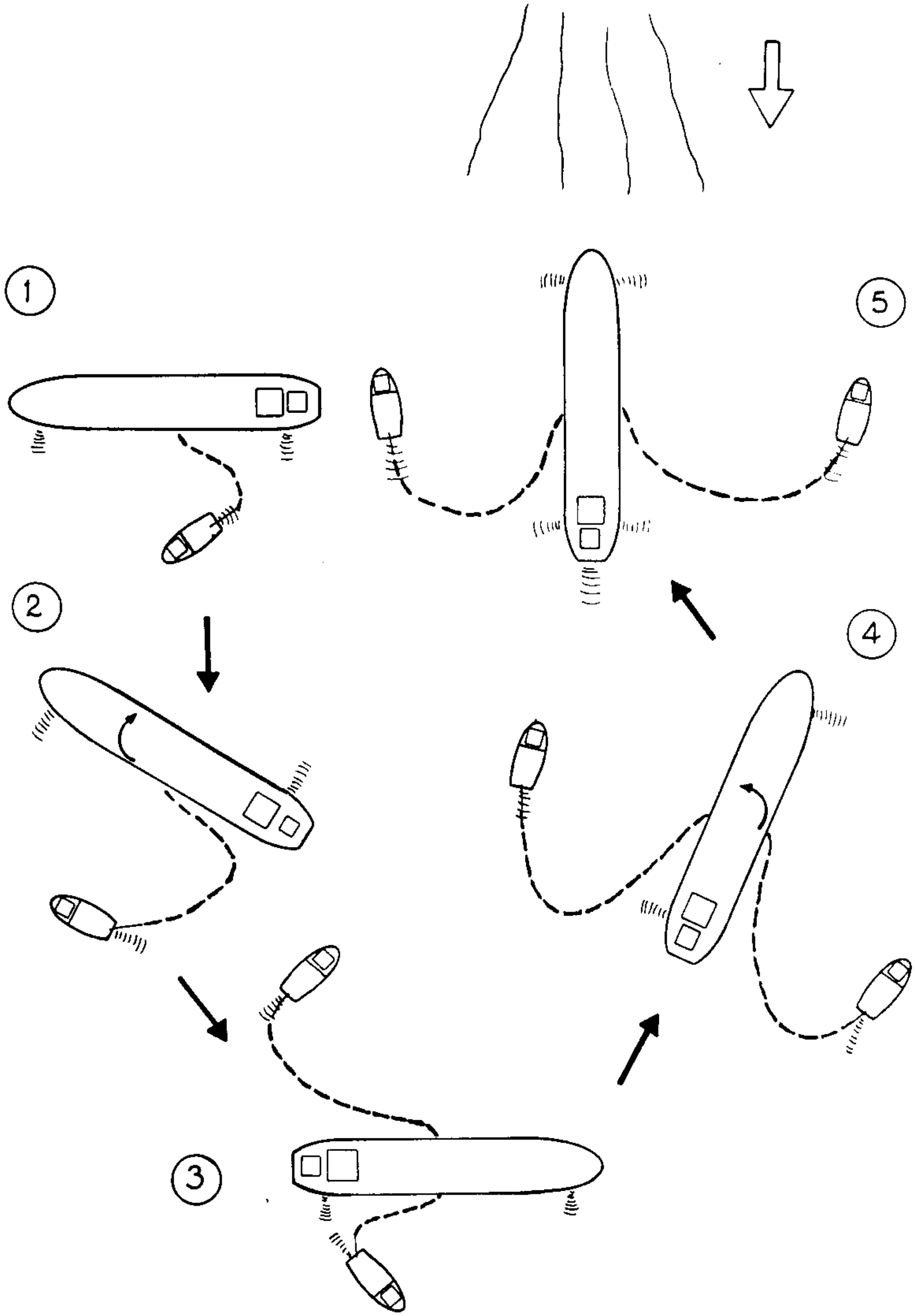


Figure 2.5.4
USE OF THRUSTERS FOR BOOM DEPLOYMENT

requiring very low oil consumption. The tanker also has to supply power to dynamic positioning thrusters, oil skimmer pumps, surge tank pumps, and processing plant. During offloading of recovered oil, the tanker also has to supply power to offloading pumps. Therefore, 50% of full power is considered necessary for the oil recovery operation. For the steam turbine engine selected, this power consumption requires approximately 480 barrels a day.

Assuming the three tugs employed for the boom towing and standby have 3000 hp diesel engines each, and consume 30% of full power during slow steaming, then each tug will consume fuel at a rate of approximately 22 barrels per day.

With these consumption rates, it can be expected that a refueling period of 45 days will be sufficient for most of the operations.

With the target recovery rate of 30,000 barrels a day, approximately 4000 tons of oil are recovered each day. Therefore, offloading shall be at least within every 22 days. More frequent offloading schedules may be necessary if the oil/water emulsion is too tight to be broken offshore by the onboard processing equipment and a large percentage of water is also to be transferred. An estimated fuel consumption of 500 barrels is necessary for each offloading pumping operation.

2.6 SHIPS SAFETY EQUIPMENT FIRE WATER AND DELUGE SYSTEM

2.6.1 Introduction

The surface collector vessel will have wide responsibilities for fire fighting and fire protection in the context of its duties as the main facility engaged in a hazardous operation. The vessel must be adequately equipped to deal with emergencies. The governing cases considered here are:-

- Ignition of the blowout fluid in close proximity to the vessel.
- Operation close to a burning gas plume.
- Deck fire caused for instance by ignition of oil spillage.
- Internal fire.
- Protection of support vessels and equipment.

2.6.2 System Description

Three systems will be required to deal with the caes listed above.

a) Firewater for cooling supplied through deluge nozzles and firewater monitors.

b) AFF (aqueous film forming) foam, to provide extinguishing capability, supplied to the monitors only.

c) Halon release capability for internal areas where fire risk is high and which are not normally manned.

Primary cooling of the vessel will be achieved by water deluge at the rate of 0.25 gallons per minute per square foot of exposed deck area, in accordance with NFPA recommendations. The water will be sprayed by elevated nozzles placed along the deck and at strategic points on the aft superstructure. Distribution weirs on the edge of the deck will allow overboard flow of the deck deluge water to cover the vessel hull.

Additionally, ten remotely controlled firewater/foam monitors on the deck and four new monitors at the aft section will supply firewater or foam as required to extinguish fires. They will also provide water cover for limited protection of adjacent support craft. The internal areas will be protected by local deluge systems, and by fire hoses.

The halon system will be supplied locally to electrical area, storage areas, and other vulnerable locations.

2.6.3 Design Basis

The major demand for firewater will be deck deluge at full rate. The exposed deck and superstructure area is approximately 100,000 square feet requiring 25,000 gallons per minute of deluge water. Fifty feet of head will be required to reach the nozzles located 15 feet above the main deck and another 100 feet of head is required for pipe and nozzle pressure losses, requiring a total of about 75 psi differential pressure from the firewater pumps.

This flowrate will be provided by two 50% capacity firewater pumps, with a third unit installed as backup. Each unit will be steam turbine or diesel driven as noted below.

Firewater will be distributed along the vessel through a 16 inch ring main with sufficient crossovers and isolation valves to enable a damaged section to be out of service without loss of the system operation.

2.6.4 Equipment Required

No	Item
3	Firewater pumps Capacity 12,500 gallons/minute Head 150 feet Submerged suction from a sea chest, via 30 inch line Each pump will be fitted with an overboard discharge operated by a pressure controlled dump valve. Two pumps will be driven by 750 HP steam turbines supplied by the ships boilers. One pump to be diesel engine driven as a precaution against boiler shutdown. The diesel driven pump will be equipped with a control and starter panel.
50	Deluge nozzles for the deck and superstructure, sprays each covering an area of approximately 2,000 square feet.

No	Item
14	Fire water and foam monitors each rated up to 2,000 gallons per minute, and capable of automatic remote operation. As indicated in figure 2.6.1, ten monitors will be located on the main deck, two at the helideck, and two on the forecastle. Additionally, two more monitors are to be placed in the lightering area beneath the helideck.
1	AFF tank sufficient to supply an hour of 1% solution to half the fire monitors. Tank size is 10,000 gallons.
2	AFF pumps each rated for 50 gallons/minute giving 200 feet of head differential.
1	16 inch ring main covering both sides of the vessel with three crossover lines, supplying both the monitors and the deluge heads, as well as the aft areas of the ship. The ring main will be equipped with fifteen isolation valves to divide it into eight operating sections foreward of the bridge, and two sections aft, any of which can be supplied from two directions. The isolation valves will be equipped with position indicators to show on the fire control panel when they are in the closed position.

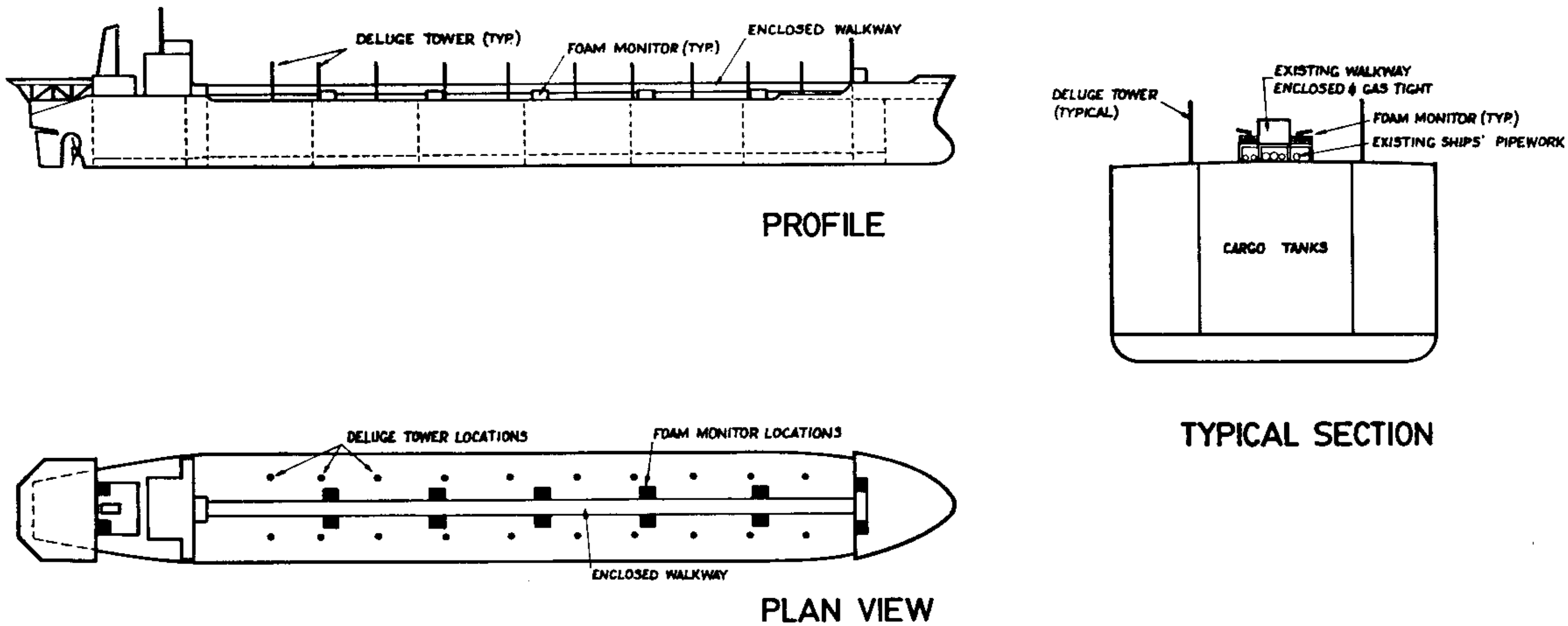


Figure 2.6.1
GENERAL ARRANGEMENT OF SHIP SAFETY SYSTEMS

2.6.5 Control System

The firewater/deluge system will be controlled and operated from a central control panel in the main control center, located behind or below the ships bridge.

The panel will contain three main sections:-

a) Overall vessel operation monitoring and shutdown systems
b) Fire and gas detection and alarm systems
c) Firewater and deluge monitoring and control system

The type of unit to be used for the service will be selected at the appropriate time. The state of the art systems are based on programmable logic controllers (PLC's) with specific programs for each input and output covering all foreseeable situations. Operator interface is provided by a VDU screen on each section of the panel and a keyboard or touch screen input unit.

The operation and shutdown section will monitor vessel operations in all areas against programmed parameter limits, and will alarm first and then shutdown equipment for its own protection. However specific conditions can be preprogrammed to override this feature where additional hazards would be created by a shutdown. For example, a generator might not be shutdown instantaneously by low lube oil pressure if another generator was not running and certain operations were in progress such as a boom retrieval in rough weather.

The Fire and Gas Monitoring section will receive input from all fire, gas, smoke and temperature rise detectors, and will integrate those to determine the situation in any area. A single detector activation will cause an alarm, requiring the operator to investigate the situation in that area, but will not shutdown essential equipment, or initiate fire fighting action. However, simultaneous activation of alarm groups will cause automatic action to be taken including halon release or deluge where appropriate.

The Firewater Monitoring and Control system will record the pressure in the firewater mains and flow at key points, the condition of all equipment in the firewater circuit, the open/shut positions of the isolation valves, level in the AFF foam tank, and the availability of the firewater pumps. On receipt of a signal requiring firewater supply, caused by a drop in ring pressure, it will sequence start one, two and finally all three firewater pumps. During operation of the system it will indicate any problems which are detected such as low flow or pressure in any area. To assist with maintenance of this critical equipment it can be programmed to record when the system and its individual components were last tested and to print out a test schedule and a list of faults for each test performed.

2.6.6 Relevant Design Codes

1. National Fire Protection Association (NFPA) 15-4

2. Det Norske Veritas (DNV) Rules for Classification of LNG Carriers

3. UK Mineral Workings (Offshore Installations) Act 1971 SI No 611 Fire Fighting Equipment Regulations 1978

4. American Petroleum Institute (API) RP 521 Guide to Pressure Relieving and Depressuring Systems

2.6.7 Determination of Deluge Water Rates

Event - Gas Cloud Ignition

Oil	30,000 BPD
Gas Oil Ratio	1000 SCF/Barrel
Gas Rate	30 Million SCFD
Calorific Value of Gas	1200 BTU/SCF
Emissivity Factor for portion of heat released at radiant heat	0.2 (API 520 Page 36 - Table 4)
Heat radiated from the flame	0.2 x 1500 mm BTU/hr = 300mm BTU/hr

Heat Capacity of Water - BTU/LB^{O}F equivalent to 200 BTU/gallon for a 25^{O}F temperature rise.

... Flow rate to absorb 300mm BTU/hr =

$$\frac{300mm}{200 \times 60} = 25,000 \text{ gpm}$$

This corresponds to an average deluge water rate of o.25 gpm/ft^2 of exposed area. The above assumption is conservative in that it assumes all of the radiated heat will reach the vessel, when in fact the maximum portion would be half for a flame directly overhead.

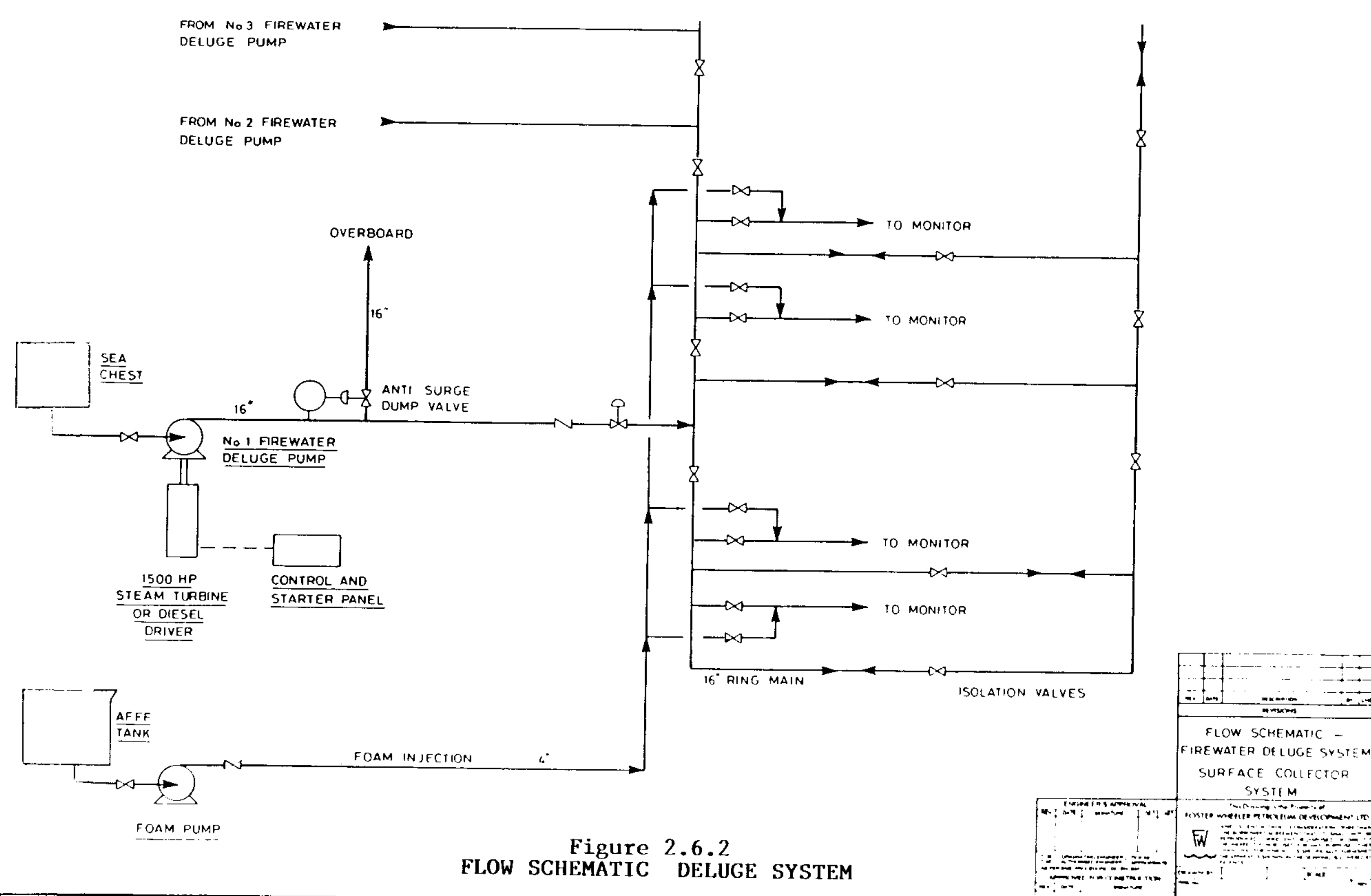


Figure 2.6.2
FLOW SCHEMATIC DELUGE SYSTEM

2.7 HOTEL AND OPERATIONAL AREAS

The vessel is divided into hotel and operational areas which are upgraded or refitted to enhance the mission-role capabilities of the vessel. The hotel areas (accommodation and normally occupied work areas), are upgraded to meet the requirements of up to 45 crew members (by doubling up some cabins) living and working in a surrounding environment equivalent to MODU Zone 1 definitions. The hotel areas can be divided into the following major zones: the aft accommodation block, the process room in the aft center tank area, the enclosed fore and aft walkway, and the enclosed forecastle machinery space (and forward spill-observation tower).

The major points of conversion of the hotel areas are as follows:

- External bulkheads insulated to S.O.L.A.S. A60 equivalent.
- No opening sidelights except in continuously manned and supervised areas.
- All entrances of the "airlock" type.
- Positive pressurization using mechanical ventilation.
- Air conditioning upgraded to "scrub" noxious and flammable fumes and gases from quarters.
- Alarm systems upgraded and extended to cover newly-enclosed or restricted areas.
- Firefighting and access capabilities improved to maximize emergency contingency capabilities.
- The addition of special purpose areas to meet operational requirements, e.g., bow spill-observation tower, etc.

The operational areas of the vessel are:

- Helideck area
- Lighter mooring area
- Oil transfer hose storage/handling area
- Boom deployment and handling area

2.7.1 Helideck Area

Mounted on the stern of the vessel at the level of the aft engine-house top, the helideck is sufficient size to allow parking of one helicopter as well as providing landing area for a helicopter up to a Bell 412 size or similar. Access is from the engine-house deck, with emergency fire fighting capabilities being provided by foam-monitors mounted forward of the helideck on the same level. A temporary collapsible/telescopic hanger is provided for scheduled maintenance or minor repair of helicopters.

2.7.2 Lighter Mooring Areas

The existing aft deck is converted to a mooring area for lightering vessels by fitting equipment to store, handle and deploy the large diameter ropes necessary to single-point moor an offloading vessel to the stern of the recovery ship. Major equipment items are mooring/storage winch, mooring bitt, stern fairleader and small tugger winches. Light hydraulic cranes mounted port and starboard on either side of the aft deck for transfer hose handling will also be used to handle the large diameter mooring ropes. The aft deck has been suitably strengthened to support this additional equipment and functions. Two foam monitors are also to be fitted in this area.

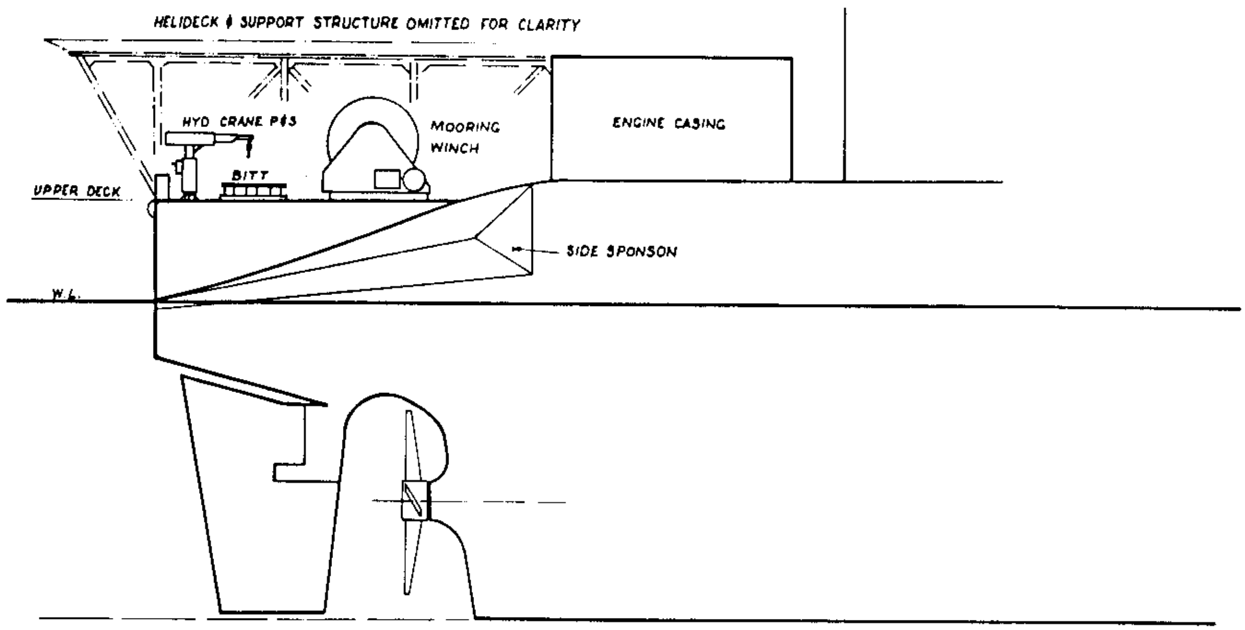
2.7.3 Oil Transfer Hose Storage/Handling Area

Incorporated into the mooring deck area and including the starboard side of the vessel forward to amidships, this area is principally a clear deck area bounded with bulwarks for the storage and handling of 12" diameter floating oil transfer hose. The aft starboard side of the vessel has a side sponson addition forming a deployment ramp for smooth ship-to-water hose transition. The hose is handled and retrieved using aft-mounted hydraulic cranes in combination with retrieval and tugger winches. The hose is stored longitudinally on the main deck starboard side in 300-400 foot lengths. The cargo discharge connection is located on the starboard side of the accommodation block, forward of the lifeboat area.

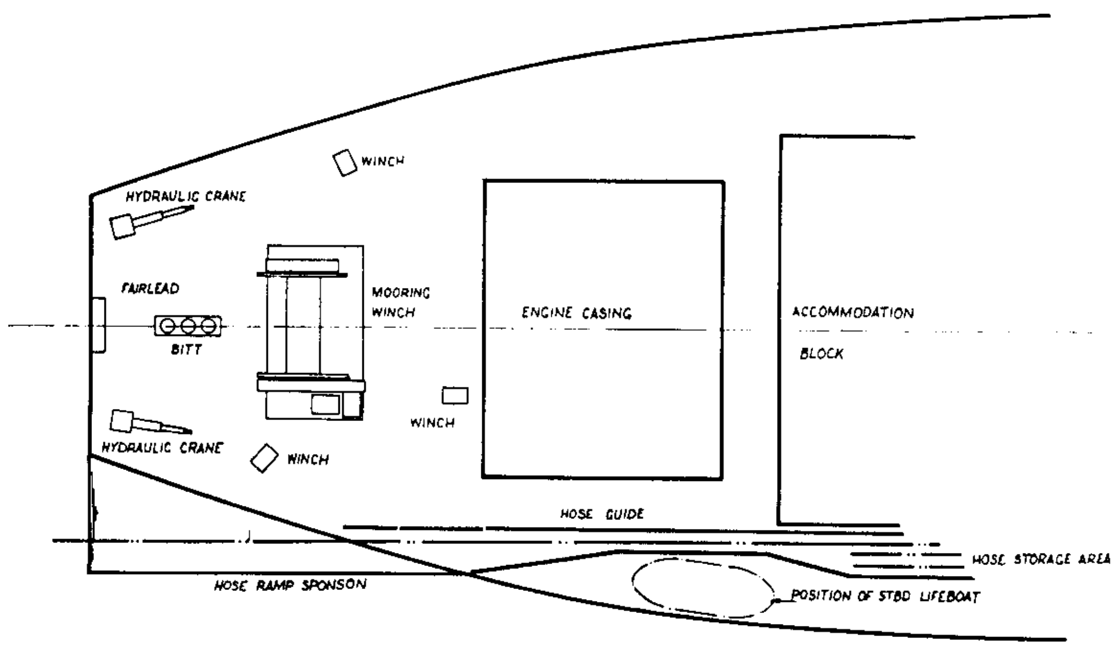
2.7.4 Boom Deployment and Handling Area

Located at the crossover area amidships, this area includes boom storage boxes (mounted on platforms P&S), associated power packs and control units, linehandling and tugger winches, lift barge and workboats storage cradles, and boom maintenance/skimmer storage area. Boom deployment lowering onto the towing vessels and skimmer handling is achieved by using the existing cargo hose handling booms in conjunction with the winches. Also located at required lengths along this area are bitts for lift barge and workboat mooring.

All deck operational areas are fully covered by a dual foam monitor system with stations located either side of the fore and aft walkway, as well as at the helideck



STERN PROFILE



PLAN VIEW

Figure 2.7.1
AFT END ARRANGEMENTS

and bow areas, and are also covered by a water deluge system as described in Section 2.6. The vessel is equipped with powerful deck floodlighting for 24-hour operations and has powerful lights located at the bow and sides to aid spill behavior observation during darkness or low visibility.

The position and layout of the hotel and operational areas are shown on the general arrangement drawing.

2.7.5 Hotel

The vessel selected has accommodation for 31 persons made up as follows:

Deck Officers	3
Deck Hands	9
Engineering Officers	4
Engineering Hands	4
Stewards Department	5
2 Cadets Pilot & Spare	4

The same size of crew with two additional men will be capable of operating the vessel. This will require certain duties be specifically allocated including:

Safety Officer	2nd Mate
Oil Treatment Unit Supervisor	1st Mate
2 Plant Operators	Deck Hands
2 Crane Operators	Deck Hands (already operating winches)
Outboard Equipment	2 additional men

Accommodation for the following additional personnel not directly connected with the ships operation is also required:

Laboratory Staff	3	(1 Scientist + 2 Technicians)
U.S. Government Representatives	2	(Staff Officer + Tech. Officer)
Oil Company/Owner Representative	1	(1 Equipment + 1 Chemicals)
Vendor Representatives: Equipment & Chemicals	2	
Subtotal	8	
Total additional personnel	10	
Additional accommodation in the Officers quarters	4	

This above manning analysis requires that two additional officers bunks and four additional crew bunks are provided.

The regular accommodation provided for 31 people is quite spacious at about 300 square foot per person. This is more than is required for normal offshore operations where regular crew changes occur. It is therefore concluded that space can be found in the existing accommodation for the additional crew with, at most, minor modifications.

2.8 Booms and Skimmers

There are at least 26 boom designs (Table 2.8.1) and 46 skimmer designs (Table 2.8.2) which are claimed to be suitable for offshore oil spill containment and recovery. Many of them are claimed to be operational in Beaufort 5 conditions. OHMSETT and the U.S. Coast Guard have performed a good number of basin tests and offshore tests on these systems in the past. Although the results of these tests are helpful in understanding how some booms perform, they may not be useful in selecting a boom for a particular application. There are several reasons for this:

- Most of the tests were performed years ago. Since then, many parts of the equipment have been improved or changed substantially.

- Only a small number of products have been subjected to similar tests, as compared to the number of products currently available.

- Tests have not always been performed with comparable conditions.

- Environmental conditions were not recorded in detail for offshore tests.

- Crews did not always have the proper equipment to deploy and handle the booms and skimmers offshore.

- No long period test results have been found to prove durability of booms over a 150 day period.

TABLE 2.8.1**

OFFSHORE BOOMS SUMMARY

MANUFACTURER	MODEL	FREEBOARD in	DRAFT in	WEIGHT lbs/ft	BUOYANCY/ WEIGHT	STRENGTH* lbs
Ajit Shah	Ocean Boom 7000	27.6	41.3	8.6		32,000
American Marine	SUPERMAX	12	24	2.9	14:1	33,000
AQUAPHYSIK	"Nessie" Half Size	12	20-25	2.2	29:1	
AQUAPHYSIK	"Nessie" Full Size	17	20-25	4.5	31:1	220,000
CECA S.A.	DEVIPOL	24	28	6	28:1	89,000
Geotech. Resources	70 Inch (1.78 m)	22.4	47.6	57	0.8:1	
Geotech. Resources	39 Inch (1 m)	13	26	36	0.8:1	
GLOBE INTERNATIONAL	OILFENCE 48	24	24	7.5	5:1	
Goodyear Aerospace	14-24 OFFSHORE	14	24	8.8	5.5:1	32,500
Hyde Products	2 Meter Boom	39	39	6.5		13,600
Hyde Products	OCEAN BOOM 1400	18	37	10.1		22,000
Hyde Products	UNIVERSAL 1050	16	26	3.7		25,000
Hyde Products	GIANT 1500	20	39	5.2		43,600
Kepner	REEL PAK™	16.5	24.5	4.5	23:1	61,500
Kepner	SUPER COMPACTIBLE™	16.5	24.5	4.0	27:1	54,000
Kepner	SEACURTAIN™ COMPACTIBLE™	16.5	24.5	4.3	25:1	54,000
Kepner	SEACURTAIN™	16.5	24.5	4.3	25:1	61,500
Kepner	SEACURTAIN™	22.0	38	6.8	28:1	71,000
Kepner	COMPACTIBLE SEACURTAIN™	21.4	38.6	10.8	17:1	122,000
NORPOL	600 OCEAN	24	35	10.5	15:1	
Offshore Devices	HIGH SEAS BARRIER	21	27	16	2.3:1	49,000
ROULUNDS FABRIKER	1500 BAY	19.7	29.5	9.1	10:1	44,400
ROULUNDS FABRIKER	2000 OCEAN	23.6	43.3	11.8	7.4:1	44,400
Versatech Products	ZOOM 24/24	21	26	5.2	34:1	9,000
VIKOMA	OCEANIC BOOM	22	36	6		46,000
VIKOMA	SEAPACK 80	27	17	3.34	73:1	

* Maximum strength of any tension member. See data sheets for strength of each tension member.

** From 1986 World Catalog of Oil Spill Response Products, by Robert Schulze Environmental Consultants, Inc.

TABLE 2.8.2*

OFFSHORE SKIMMERS SUMMARY

MANUFACTURER	MODEL	SERVICE TYPE	WEIGHT (lbs)	MAXIMUM CAPACITY (gpm)
ABASCO	PETRO-MOP	Rope mop	50,000	
Ajit Shah	Walosep W 2	Weir	1,000	264
Ajit Shah	Walosep W 4	Weir	1,400	528
Ajit Shah	Walospeed	Weir	2,100	
Adjit Shah	Swedtrawl	Boom Skimmer	778	
ALSTHOM ATLANTIC	CYCLONET 100	Vortex	4,400	790
ALSTHOM ATLANTIC	CYCLONET 120	Vortex	8,800	790
ALSTHOM ATLANTIC	CYCLONET 150	Vortex	19,850	1,600
Biggs Wall	Springsweep	Weir	13,200	
CECA S.A	STOPOL 120	Drum	2,640	176
CECA S.A	STOPOL 200	Drum	3,300	220
Schiffswerft	THOR	Weir	250 DWT	440
Schiffswerft	BOTTSAND	Weir	650 DWT	616
Hyde Products	Skimmer DS 150	Weir	295	110
Hyde Products	Skimmer DS 210	Weir	520	300
Hyde Products	Skimmer DS 310	Weir	1,010	700
Frank Mohn	ACW-402	Disc/weir	17,800	1,760
Frank Mohn	Arctic	Disc/weir	33,300	
JBF Scientific	DIP 5001	Submersion belt	190,000	500
JBF Scientific	DIP 6001	Submersion belt	840,000	1,100
JBF Scientific	DIP 7001	Submersion belt	560 tons	1,100
Lockheed	Type 4000	Disc	17,000	1,000
LPI	66	Submersion plane/weir		3,430
LPI	110	Submersion plane/weir		8,640
LPI	220	Submersion plane/weir		24,640
MARCO	36 foot Class V	Sorbent lifting belt	18,500	250
MARCO	50 foot Class VII	Sorbent lifting belt	34,000	500
MARCO	70 foot Class TOR-70R	Sorbent lifting belt	190,400	250
MARCO	Class XI V.O.S.S	Sorbent lifting belt	4,500	
Morris International	MI-250C	Disc	2,000	600
Offshore Devices	VOSS	Boom-skimmer	4,650	750
Offshore Devices	High Seas Barrier	Boom-skimmer	17,500	750
OIL MOP	MARK IV-160P	Rope mop	8,000	140
O.P.E.C	FORCE 7 SERIES 2	Rope mop	14,080	
OMI	APWB SERIES 3	Rope mop		
PHAROS MARINE	GT-185	Weir	350	200
Thune-Eureka	EUROSKIM 1	Disc	59,744	572
Thyne-Eureka	EUROSKIM 2	Disc	11,463	572
Thune-Eureka	EUROSKIM 3	Disc/weir	4,410	572
TRACOR MARINE	SOCK	Suction/weir	7,000	154
Versatech Products	MK 13 ARCTIC	Sorbent submersion belt	13,000	110
Versatech Products	MK 9	Sorbent submersion belt	100,000	350
VIKOMA	SEASKIMMER 50	Disc	1,556	200
VIKOMA	SEASKIMMER 100	Disc	2,205	415
VIKOMA	WEIR BOOM	Boom skimmer		2,000
VIKOMA	SEAWOLF	Disc	1,333	

* From 1986 World Catalog of Oil Spill Response Products, by Robert Shulze Environmental Consultants, Inc.

The above reasons have made the equipment selection extremely difficult.

Attempt is made here to select a system that will perform well in most conditons anticipated, but not in special conditions such as fire resistance, cold weather, extremely light or heavy crude, aged oil clumps, and large debris. When any of these special conditions occurs, special equipment has to be purchased and installed. No equipment currently on the market can handle all of these conditions.

The Selection of Oil Booms and Skimmers

There are many parameters important to the proper selection of oil spill equipment. The design criteria for the off-shore oil collection system requires compatibility between oil booms, oil skimmers, oil recovery rate, sea state, and a range of oil types to the skimmer selection. Table 2.8.3 shows skimmers selected based on pump capacity (>437.5 gpm) and oil type (handle at least 2 types) and sea state (>3). Note the sea state shown in this table is that defined in the World Catalog of Oil Spill Response Products. It is different from the Beaufort scale as discussed in Section 2.3. Sea state 4 is approximately equivalent to Beaufort 5. A look at the oil recovery rate and size compatibility and construction of the skimmers indicates there are very few skimmers (Walosep W4, LPI-66, Voss, and High Seas Barrier) can be used by the oil recovery tanker system.

The LPI-66 is a 66 foot submersion plane skimming the barge. Although it is the smallest of the three LPI models, maneuvering in the oil boom surrounded waters may still be difficult. Therefore, it is not recommended for use in the oil recovery system in spite of its large pump capacity.

TABLE 2.8.3
OFFSHORE SKIMMERS
Selection based upon pump capacity, oil type, and sea state

Manufacturer (location)	Model	Pump Cap. (GPM)	Oil Type	Max Sea State	Recovery Rate (GPM)	Largest Dim. (ft)	Remarks
Ajit Shah (US West C.)	Walosep W4	528	L,M,H	5	Not Known	9.0	no test results available
Alsthom Atl. (US Gulf C.)	Cyclonet 100	790	M,H	4	36M,45H	9.8	capacity too small
Alsthom Atl. (US Gulf C.)	Cyclonet 120	790	M,H	4	?	11.8	capacity too small
Alsthom Atl. (US Gulf C.)	Cyclonet 150	1600	M,H	4	?	14.8	capacity too small
Luhring Schif (W. Germany)	Bottsand	616	M,H	?	616	152.0	too big
Hyde Prods. (US Gulf C.)	Skimmer DS310	700	M,H	?	400	11.5	capacity too small
LPI (US Gulf C.)	66	3430	L,M	4	?	66.0	pump rate questionable
LPI (US Gulf C.)	110	8640	L,M	4	?	110.0	too big
LPI (US Gulf C.)	220	24640	L,M	5	?	220.0	too big
Morris Int. (Canada)	MI-250 C	600	L,M,H	6	?	7.8	no test results available
Offshore Dev. (US East C.)	VOSS	750	L,M,H	6	530	65.0	boom-skimmer, boat mounted
Offshore Dev. (US East C.)	Hi Seas Ba.	750	L,M,H	6	530	612.0	boom-skimmer, fixed buoyancy
Vikoma (England)	Wier Boom	2000	?	5	1500-2000	33.5	boom-skimmer, air buoyancy

NOTES:-

Skimmer must be reasonable size.
Skimmer must be compatible with containment boom.
Oil recovery rate must be greater than 437 GPM.
Sea state capability must be greater than 3.
Skimmer must be capable of handling at least two oil types.

The Voss and High Seas Barrier are of similar design and capacity except the Voss is a boom type weir skimmer towed alongside a service boat whereas the High Seas Barrier incorporates this skimmer with the oil boom into a complete skimming barrier. These two skimmers have been designed for use by the U.S. Coast Guard and are now standard equipment used by the Coast Guard National Strike Force for containment/recovery service. The High Seas Barrier has been extensively tested by U.S. Coast Guard and OHMSETT and has been proven to be operational in 20 knots wind, 5-6 foot waves, and 1.5 knots current. It is also been shown that the barrier was able to contain oil in over 12 foot seas showing only small entrainment. Furthermore, as the High Seas Skimming Barrier is standard equipment used by the Coast Guard Strike Force, the U.S. Coast Guard is recognized to be a source of emergency supply.

The Skimming Barrier also has the function of oil containment boom. Complete compatibility between the boom and skimmer has been included at the design stage. Therefore, it is recommended to adopt the High Seas Skimming Barrier as the standard equipment for the oil recovery system.

The Walosep W4 Skimmer is a new design and has not been tested for its capacity. However, the skimmer has a diameter of 9 feet and relatively low cost. It is selected for use as a back-up unit in case the Skimming Barrier is clogged or otherwise fails. The small diameter is also well suited for operation in the "U" shape region of the Skimming Barrier.

2.8.2 Description of Skimming Barrier System

The Skimming Barrier manufactured by Offshore Devices, Inc., consists of a 612 foot long, 48 inch vertical, costed fabric curtain with 102" rigidizing struts. The six center struts incorporate skimming weirs and sump tanks. It can be packaged in two 20 foot Fruehant Containers including the pumping subsystem. The boom can be rapidly deployed from these containers. The pumping station contains three lightweight double acting diaphragm pumps capable of passing 3" (7.62 cm) debris. The system is driven by remote hydraulic power sources. When deployed, the barrier has 21 inch freeboard and 27 inch draft. The combination of both rigid foam and inflatable flotation devices permits a small storage package, as well as positive buouancy even when not inflated.

Experience with this boom and wier system indicates that the system can meet the design specifications, as well as, or better than, most other systems on the market. It suffers from abrasion and other forms of damage during recovery, especially, but once deployed it has been shown to work well in field operations.

The boom is deployed in a "U" configuration. It is packaged in a floatable container which will be lowered onto the deck of one of the tug/supply vessels by the collector vessel's crane. One tension line extension is then accessible from the opened container. This will be made fast to the collection tanker at a special sliding connection. The workboat then slowly moves away with the crew carefully deploying the boom over the open transom. The floats automatically inflate as each leaves the container. The main components of the Skimming Barrier system are illustrated in figures 2.8.1 through 2.8.3

The skimmering weirs located the at the apex section of the boom, collect oil into the sump tanks. Behind these sump tanks is a pump float with six inlet hoses connected to the sump tanks and three diaphragm pumps powered by remote hydraulic sources. The pump connections are made by the stand by tug after the boom is deployed.

The oil emulsion flows over the weirs and in to the sump tanks and diaphragm pumps which then pump the collected fluids along the recovered oil hose to the lift barges. Thus the main objective is to concentrate the oil slicks into the apex of the boom's "U" formation.

2.8.3 Principle Equipment Required to Run the Skimming Barrier

i. The Skimming Barrier

Two sets of the 612 feet skimming barrier manufactured by Offshore Devises, Inc., each complete with the six center weir skimmers, sump tanks and hydraulic double acting diaphragm pumps During oil recovery, each Skimming Barrier is towed in a "U" configuration on one side of the

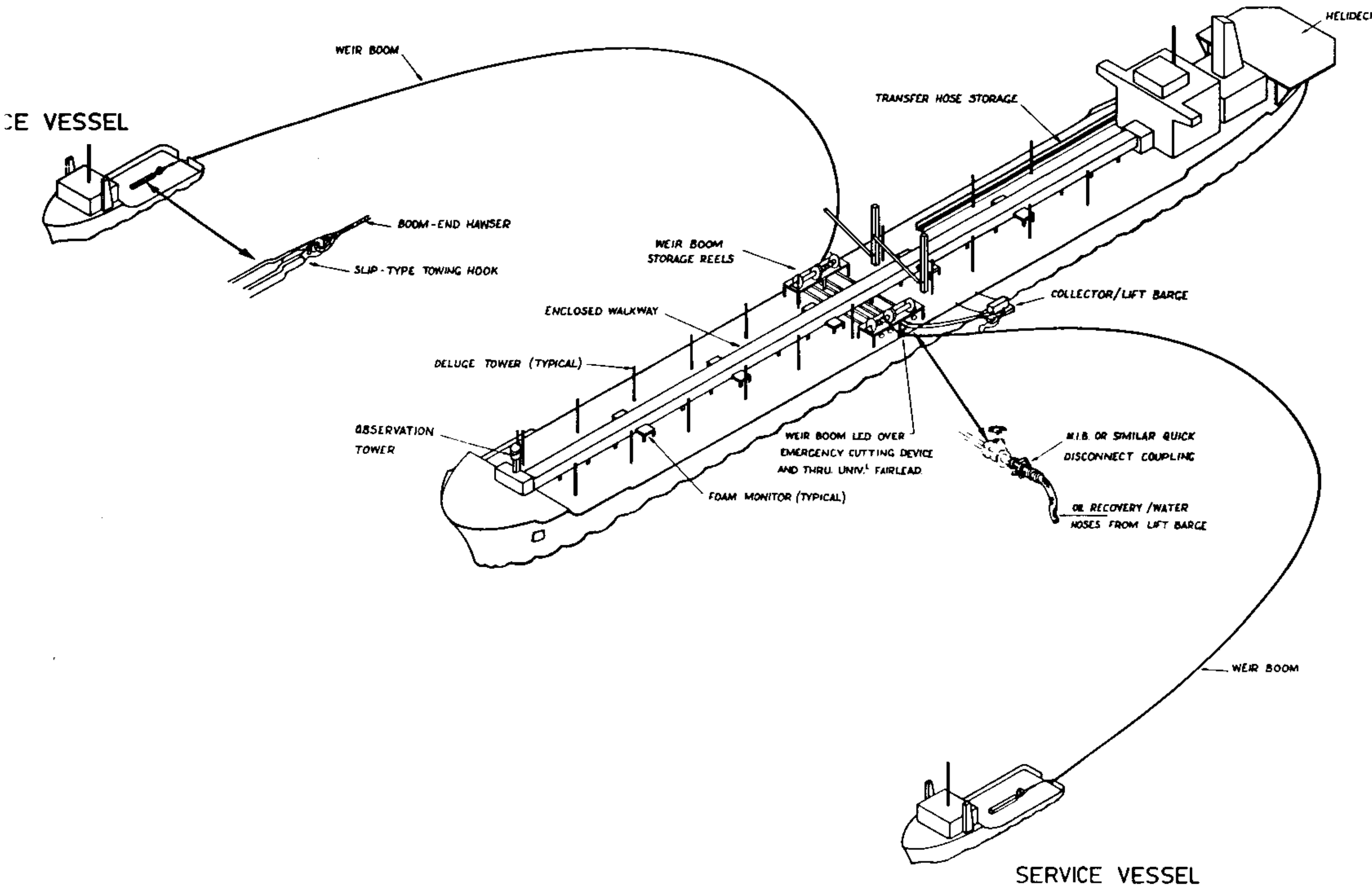


Figure 2.8.1
SCHEMATIC OF DEPLOYED SYSTEM

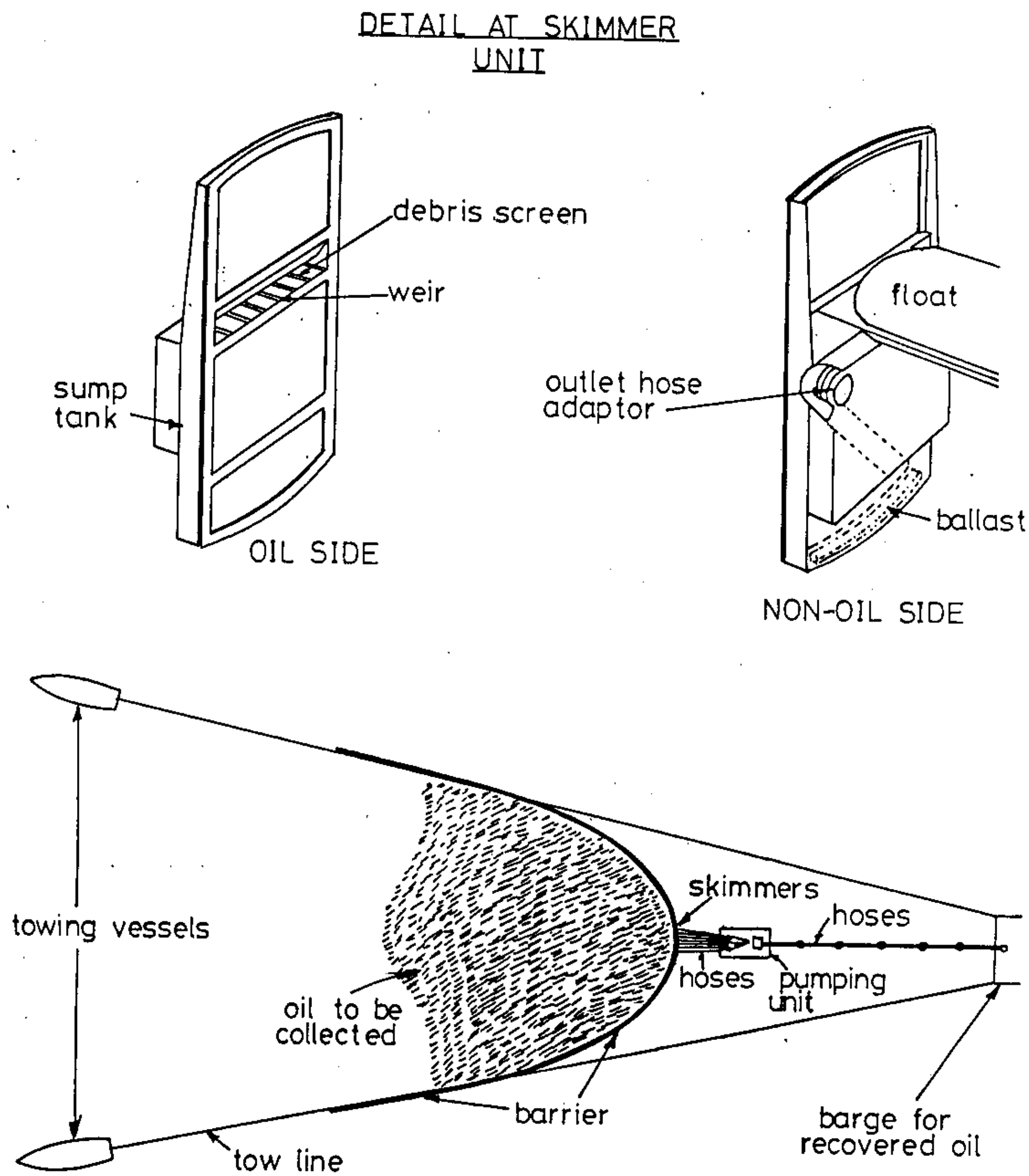


Figure 2.8.2 HIGH SEAS SKIMMING BARRIER configured as tested and operated by USCG

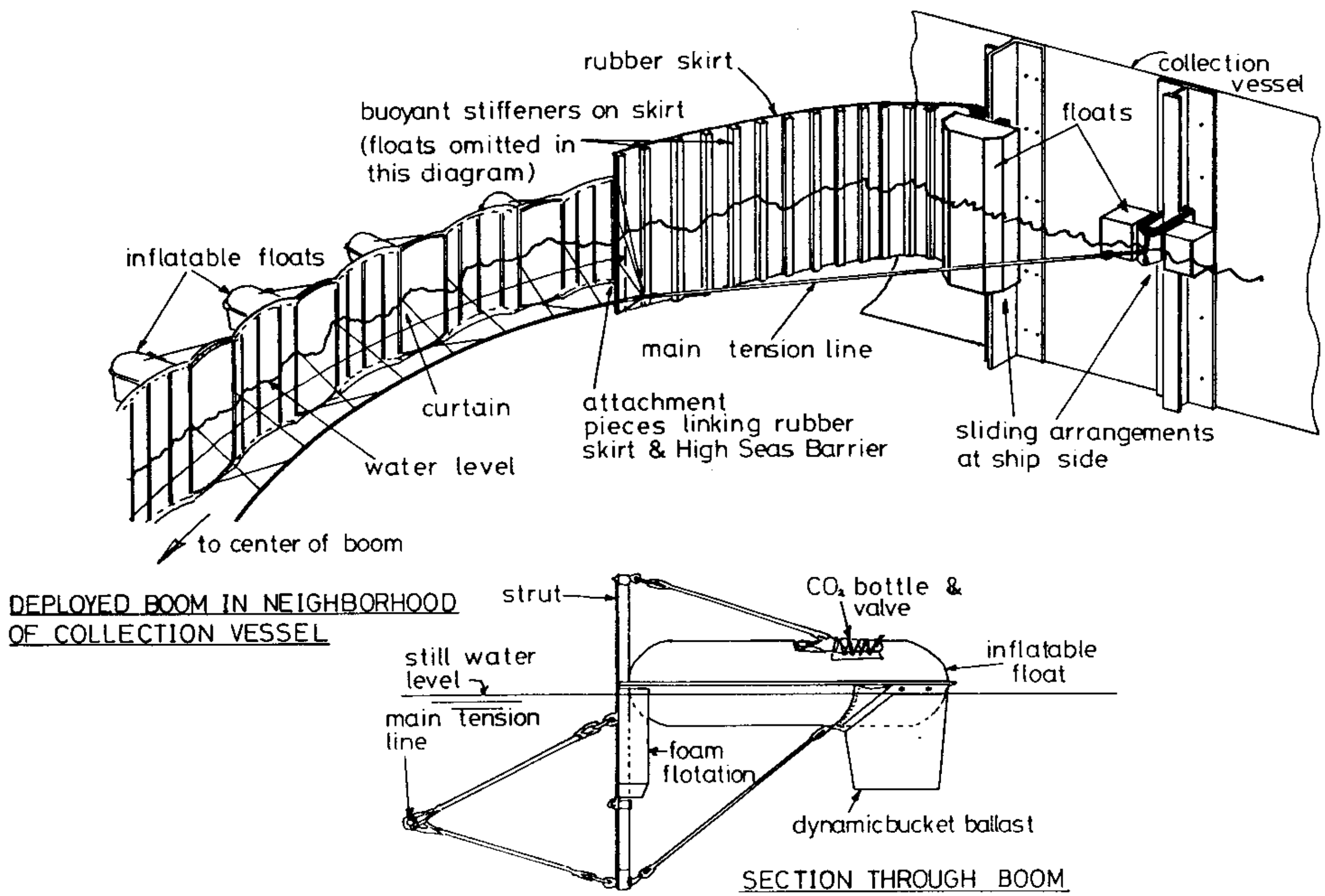


Figure 2.8.3 BARRIER ATTACHED TO COLLECTION VESSEL

NOTES RELATED TO FIGURES 2.8.3 AND 2.8.4

1. Boom attachment to the surface collector vessel must overcome two problems. Firstly the ship may have rough marine growth at and below its ballast water line. This roughness will cause rapid wear of the boom materials if they are frequently in contact. The second problem is that the boom has been designed to be surface following, but the ship sides will be moving up and down with the rigid body motions of the ship.

2. In order to separate the boom from contact with the ship side and inevitable abrasion, a sliding connection with a buoyant surface following device has been designed. This device is attached to a rubber skirt which is deeper than the containment boom sections. The design provides for a seal using a replaceable reinforced rubber strip (fig 2.8.4). This strip is mounted on the buoyant sliding framework and makes contact only with the special stainless steel bracket upon which the whole assembly is mounted. This bracket is then bolted to special stainless steel studs, fixed previously in the ship's side during the vessel's conversion.

3. The deep rubber skirt is itself extremely tough, being made from the same reinforced rubber material as hovercraft skirts. The sliding mechanism, on stainless steel rollers with internal bearings, holds the skirt off the ship's side with a stainless steel backing plate, although some contact is inevitable. The buoyant ballasted stiffeners and floats on the skirt are designed to hold it upright and stable. The skirt is attached to the boom at a distance of approximately 15 feet from the ship side attachment. The connection between the skirt and the boom involves a small amount of field modification to the boom, but this is not a significant item of work, and can be performed in the field for each replacement boom to be deployed.

4. In order to accommodate relatively large ship side vertical motions (up to 3 meters, or 10 feet, see tables 2, 3, and 4 in Section 2.3) the attachment of the skirt is on a sliding system designed to follow the water surface as the ship side moves. Additionally the skirt has a greater depth than the boom, allowing for the inevitably greater motions at the ship side attachment point.

5. The boom towing line is also attached to a sliding mechanism at the ship's side. This attachment is also on a stainless steel roller sliding mechanism, with floats so that it too is surface following. By the above described techniques, the ship motions are largely decoupled from the boom, and from the boom towing line.

6. Since rather large draft changes of the collection vessel are to be accommodated, it is necessary that the sliding arrangements can accommodate up to 40 feet of movement of the still water line, plus dynamic movements. This dictates that they must be some 55 feet longs, which creates handling problems. Therefore, a special connection has been designed which enables the attachment of the mounting brackets in segments no longer than 12 feet. The joints are such that the sliding feature is uninterrupted. The vessel must be taken to ballast draft for installation of the lowest sections, but if operations are planned so that the vessel is maintained at deep draft by using extra ballast (as suggested in Section 2.3, to minimize motions) the lower 12 feet of side connection brackets can be left off. Once the stainless steel brackets are attached, the side cranes will be used to fit the sliding buoyant devices onto the brackets, and top capping pieces will be added to prevent lift off of the sliding devices at deep draft and large sea states. Capping pieces are also fixed to the bottom sections of each attachment bracket.

7. In order to minimize sliding resistance, all components of the sliding connections, including the mounting brackets are to be of high grade marine stainless steel (eg A316) throughout.

8. The general configuration of the system is shown in figures 2.8.2 to 2.8.4.

tanker. The opening of the "U" shall be about 400 foot wide. The system configuration is shown in figures 2.8.2 and 2.8.1 Two additional skimming barriers are to be procured immediately. The collection operation is called for, to be used as back-ups as needed.

ii. **The Main Hydraulic Power Pack**

This is a self contained diesel driven unit with the tanker main engine driven system as a back-up which supplies hydraulic power to the Skimming Barrier pumps. The main hydraulic power pack is located on the lift barges when the system is deployed.

iii. **The Recovery Pumps**

The recovery pumps located on the lift barge are hydraulic double acting diaphragm pumps of compatible capacity and debris handling characteristics with the Skimming Barrier pumps. These pumps transfer the recovered oil from sea level, to the storage tanker, with the aid of vacuum pumps located in the tanker, and after steam, or hot water has been injected (as necessary), depending upon the temperature and oil type) to the collected oil/water mixture, on the lift barges.

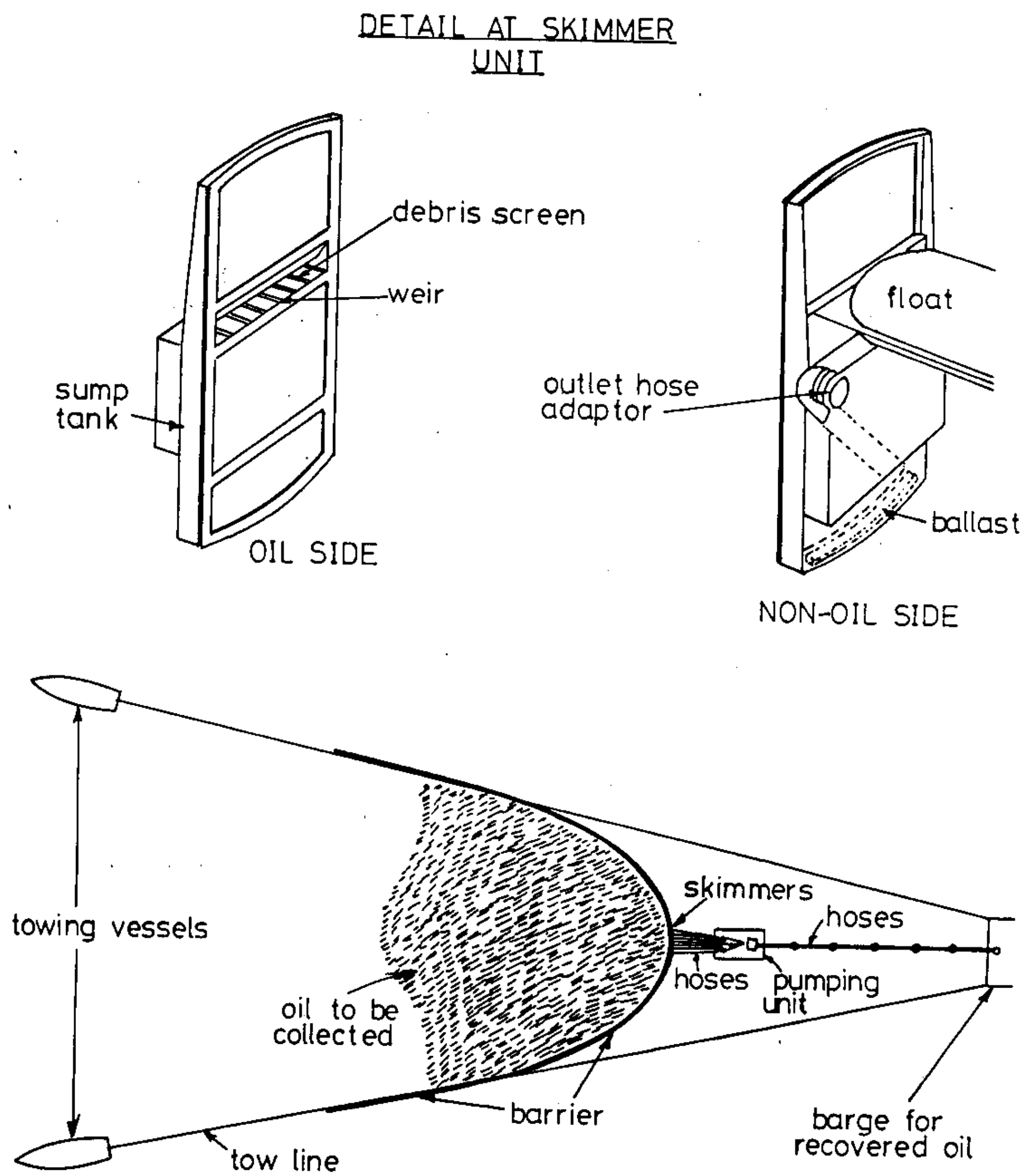


Figure 2.8.2 HIGH SEAS SKIMMING BARRIER configured as tested and operated by USCG

iv **The Cranes**

New pedestal cranes on either side of the tankers are used for deployment of the Skimming Barriers and associated equipment. The Barriers are set down onto the decks of the towing vessels. The cranes are also used to deploy and recover the lift barges. They are mounted on the deck of the tanker near the boom offloading point. These cranes replace existing equipment on the tanker.

v **The Auxiliary Hydraulic Power Pack**

This is the same as the main power system and serves as a backup system in the event of main hydraulic power pack failure.

vi **Barrier Connection at Tanker Side**

Serious chaffing and mechanical damage to the boom will be minimized at the ship's side by use of sliding attachment mechanisms, as illustrated in Figure 2.8.4. These attachments are buoyant and slide on rollers mounted in stainless steel slot arrangements which are bolted to the ship's side at the commencement of the collection operation. The main tension line from the boom is attached to a float on an articulated arm which connects to the foreward sliding device. To prevent oil leakage betwen the boom and the ship's side, a deep rubber skirt is attached to the second sliding device. The skirt is eight feet deep and has stiffeners and floats at intervals along its length of both keep it vertical and to give it good surface following characteristics while remaining close to the moving ship's side. The large depth will prevent overtopping and leakage beneath the skirt in conditions up to and above Beaufort 5, even with beam waves and light ship conditions (see Section 2).

2.8.4 Lift Barges

Sections 2.8.1 - 2.8.3 have described the Offshore Devices Skimming Barrier System and deflector boom. An additional feature of the system proposed in this document is a lift barge where waxy crudes and highly emulsified oil/water mixtures will be given immediate heat treatment by injection of either steam or hot water, before they are pumped up onto the tanker. Furthermore, the lift barge has a surge chamber where all flow is mixed and smoothed before pumping up to the ship. Oil/water mixtures from the Skimming Barrier and from additional skimmers will be gathered at each side of the ship, at these lift barges, located behind the boom. Flow lines to the lift barges will be flexible floating hose type. The lift barges are illustrated in figure 2.5.2.

As stated elsewhere, there is such a wide range of oil types that it cannot be guaranteed that the system will always be capable of working with the target efficiency. However, provision for pumping capacity of more than twice the target blowout rate and provision for heat treatment immediately, at sea level, will enable a wide range of oil types to be collected satisfactorily.

2.8.5 Skimmers

The Skimming Barrier system alone has more than adequate capacity to collect oil and oil water emulsions that are not extremely thick and heavy. In the event that the oil type results in clogging of the weir booms, stand by skimmers are provided that are capable of dealing with the more difficult mixtures, to a limited degree. The Walosep Skimmer is proposed, although replacement skimmers may be provided during operations specially selected for their performance with the specific oil conditions encountered. Deployment of the skimmers is to be undertakne with the ship's cranes.

2.9 DISPERSANTS

2.9.1 Decision to Use Dispersants

A decision process for using chemical dispersants for oil spills has resulted from 800 hours of committee effort by 125 people in U.S. Coast Guard Federal Regions I, II, and III. The decision process is described in figure 2.9.1 below, taken from reference 3.

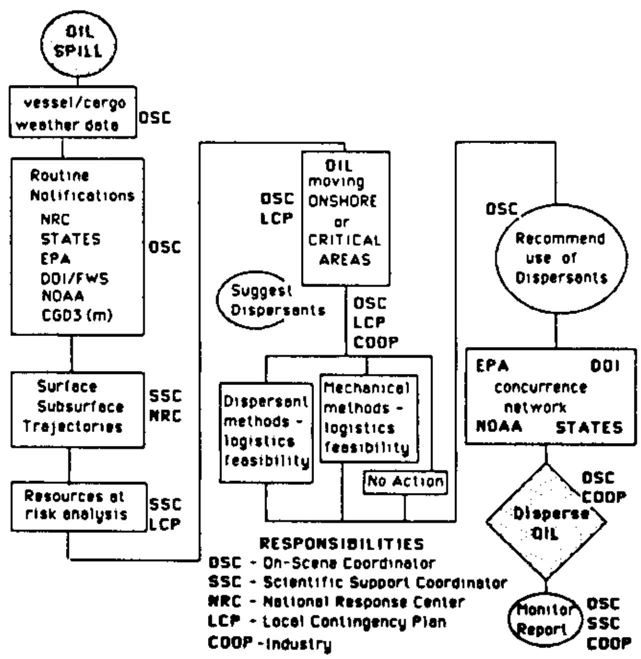


Figure 2.9.1 The Dispersant Decision Process

When dispersants are used, the OSC is charged with monitoring their use.

Essentially dispersants work by reducing interfacial tension between oil and water. Moreover, the amount of dispersant to be used in any given circumstance is still a matter of much international debate. The smaller the droplets of dispersant are when they meet the oil/water, the more effective they are likely to be. Hence spraying techniques are always advocated. Reference 4 lists tests at sea undertaken in a number of countries, including Canada, France, The Netherlands, Norway, the UK and the USA.

Despite the number of trials that have been performed, there exists no clear picture as to the conditions under which dispersants are most effective. In general terms, it is concluded that the higher the sea state, the more effective the dispersion of oil is. This is only due in part to the presence of the dispersant. In flat calm conditions, it has been found that very little dispersion may result if spraying from the air is the means of application. If boats are used, especially with surface breaker boards, dispersion is increased.

The use of the main collection vessel in this study is primarily for the collection and storage of oil, with collection rate being much higher than for any other existing system. It is not felt to be practical or efficient to combine dispersant spraying from this vessel with oil collection. However, where there is an immediate threat to a nearby coastline, and where the use of dispersants is permitted, a parallel dispersant spraying operating may take place. Hence, it is proposed that the collection vessel will be equipped with a store of dispersants and with one set of dispersant spraying apparatus that will be mounted on the field helicopter and another set that will be mounted on the standby boom towing vessel. Additionally, it is proposed that a completely separate dispersant spraying operation is mounted from the shore.

In conditions up to Beaufort 5, when oil collection is taking place, the field helicopter may be used to make regular runs, downstream of the collection operation, and to spray dispersant. This activity may be supplemented in calm conditions by use of the standby boom towing vessel, which will have its own spraying equipment.

2.9.2 Quality of Dispersant Required

The experience of many experts indicates (reference 5) that a modern, high-efficiency dispersant can be expected to disperse on the order of 10 parts of oil for each part of dispersant that is used. This is lower than in the laboratory for a variety of reasons, including windage losses, inaccuracy of placement and variation of oil thickness on the water.

In the absence of a threat to a sensitive shoreline, a major consideration in the decision on how much dispersant to use is the resulting concentration of dispersed oil in the water that will result. A maximum allowable value should be the concentration at which little or no toxicity to sensitive marine organisms is observed, using either the dispersant or the dispersant-plus-oil mixture. For most modern dispersants, typical concentrations causing fifty percent mortality to marine organisms are on the order of several hundred parts per million.

The table overleaf, taken from reference 5, indicates that in water depths greater than 20 meters, even a thick oil cover may be safety dispersed. A criterion selected in this reference is 10ppm as being the maximum allowable concentration of oil plus dispersant in the water column. It is also assumed that the dispersant will occupy the full water column, once applied, and that oxygen will be supplied from the atmosphere, as a result of wind and wave action, in amounts that will be sufficient to replenish that used up by biodegredation and photo-oxidation. In practice, these conditions will be met in conditions above Beaufort 3.

Concentration of dispersed oil in water as functions of oil thickness and water depth

Appearance of oil on water	Approximate oil thickness (mm)	Concentration of dispersed oil in water (ppm) if uniformly mixed, when the water depth is: 1m	2m	5m	10m	20m
Barely visible	4×10^{-5}	0.05				
Silvery sheen	8×10^{-5}	0.1	0.05			
First trace of color	1.5×10^{-4}		0.2	0.1	0.4	
Bright bands of color, iridescent	3×10^{-4}		0.4	0.2	0.07	0.04
Colors tend to be dull	1×10^{-3}	1.2	0.6	0.2	0.1	0.06
Colors are fairly dark, little evidence of rainbow tints	2×10^{-3}	2.4	1.2	0.5	0.2	0.1
Brown or black	0.01	12.	6.	2.4	1.2	0.6
Black/dark brown	0.1	120.	.60.	24.	12.	6.

Notes: 1. The correlation between oil thickness and the appearance of an oil slick on water is correct in theory. In practice, the following conditions may affect the ability to observe oil on water: distance of the observer above the water surface, roughness of the water surface, and direction of viewing compared with the direction toward the sun. If viewed under some conditions (e.g., viewed toward the light source), an oil slick will reflect light and could appear relatively silvery, regardless of oil thickness.

2. In view of these considerations, care should be used in estimating the thickness of an oil slick from its appearance. Whenever possible, other methods of estimating slick thickness also should be used. Examples of other methods include direct measurement (usually this is very difficult) and calculation of thickness from volume of oil spilled divided by the area covered.

Application should be supplemented from this shore based marine operation, by fixed wing aircraft. During "normal" operations, if the recovery operation is 95% effective (a target up to Beaufort 5) then the field helicopter, together with the standby boom towing vessel in calm conditions, could be used to spray limited amounts of dispersant on a planned daily basis. A barrel of dispersant weights about 350 pounds. The field helicopter is not proposed to be capable of carrying more than four barrels plus the pilot and the spraying equipment. Ten spraying trips per day would result in application of forty barrels of the dispersant under these circumstances using the helicopter alone. This demand is heavy upon the pilot(s) with all their other obligations, and although feasible is not felt to be highly desirable on a continuous basis for the duration of the oil collection operation. Hence, where there is a need to use dispersant, the application should be largely by the standby boom towing vessel, supplemented by the field helicopter, using the helicopter to direct the boat to the areas requiring treatment. It is not known how much difficulty may be experienced at night in identifying the oil patches on the water that have escaped the main collection system. Therefore, it is proposed that a planned steaming path is developed during the day by the third boom towing boat, when used for dispersant spraying, and that careful notes are made about the most effective maneuvers in any set of environmental conditions at the particular blowout location. In the event that it is impossible to locate the oil at night which is desired to be dispersed, the boat can simply repeat the most appropriate maneuvers found to be effective in similar conditions during the day.

The application of dispersant in the manner described, with the modest ambition of dispersing only 5% of the oil from the blowout, results in a significant demand for dispersant. Clearly this demand cannot be met for many days from a dispersant store on the collection vessel. Thus the need for a separate shore based supply operation is evident.

It is proposed that the collection vessel is equipped with a store of 1,000 barrels of dispersant.

2.9.3 Dispersant Type

Several oil dispersing chemicals are commercially available. Examples are Corexit 9527, Corexit 9550, Finasol OSR-7/5, EC.O Atlantol AT-7, OFC D-609, Dispolene 32S, Shell DC BPMA 1037. Under different environmental conditions, and with different types of oil, each dispersant may be found to have a different effectiveness. Corexit is probably the most frequently used dispersant in the USA, and has been found to perform as well as the other chemicals mentioned here. In the absence of much price differential, Corexit 9527 and 9550 are selected for storage on the collection vessel in equal quantities.

2.10 LIGHTERING

Lightering, the offloading of the recovered oil or oil/water mixture, will take place using an oil tanker of similar dimensions and capacity to the recovery ship. No special equipment of fittings are needed on the lightering vessel on or above the normal standard for ships of this type and service, although bow thrusters are highly desirable. A description of the actual lightering scenario is as follows:

A suitable vessel is called and scheduled to arrive at the blowout site as the recovery vessel approaches full capacity. The lightering vessel approaches the blowout site on a heading against the prevailing conditions and takes up station 300-400 feet astern of the recovery vessel. A light mooring-header line, with a head-buoy attached, is carried from the stern of the recovery ship by a workboat or service vessel, and is fed-out and taken to the bow of the lightering vessel. After pick-up, by graphnel, the header line is taken to a captsan winch or wildcat and is used to pull the heaver (10" diameter nylon) mooring line from the stern of the recovery ship to the bow of the lightering vessel where it is secured for the offloading operation.

The offloading hose, a floating hose, which is stowed longitudinally on the starboard side of the recovery ship, is fed over the stern ramp-sponson from where it is towed to the midship cargo crossover area of the lightering vessel.

The hose handling booms or cranes, which are a normal feature for vessels of this service, are then used to lift the end of the buoyant offloading hose onto the vessel's deck where normal loading connections are made. The recovery ship end of the hose is connected to a discharge connection, located near the aft starboard side of the accommodation block, and offloading commences. The offloading, using a 12" line, is expected to take approximately 15 hours. During this period, the service vessel will maintain station near the lightering vessel to aid in controlling any undesirable motions of the tethered vessels, e.g., "fish tailing" of the lightering vessel. The D.P. capability of the recovery vessel will also play an important part in this function. After offloading, the recovery of the hose and mooring line takes place.

The hose is pulled back up the stern ramp using tugger winches and is stored in 300-400' sections on the deck of the recovery ship. The mooring line is recovered using the mooring line storage winch located on the aft deck of the recovery vessel.

Figure 2.7.1 shows the stern of the recovery ship suitably converted to facilitate the lightering operation.

2.11 PROCESSING EQUIPMENT

2.11.1 Introduction

The results of the literature survey have been examined regarding the type of system to be used. A search of literature has been carried out to obtain information on the quality of crude oil typically recovered from the sea using booms and skimmers. Process schemes have been devised to handle this type of fluid to a point where it can be economically stored and transshipped. These systems have been developed to optimize integration with the shipboard systems available.

2.11.2 Design Basis

- 30,000 B/D of medium gravity parafinic (waxy) crude oil accompanied by considerable gas evolution.

- Evaporation of the crude is expected to be in the range of 20 percent in six hours to 40 percent in 24 hours.

- The kind of crude oil considered can form light emulsions after about 24 hours in the water and heavier "chocolate mousse" emulsions after longer periods.

- The skimmers can recover oil and light emulsions with equal volume of sea water.

- Heavy emulsions contain about 70 percent water and are lifted with an equal volume of sea water but at a lower rate than with fresh oil.

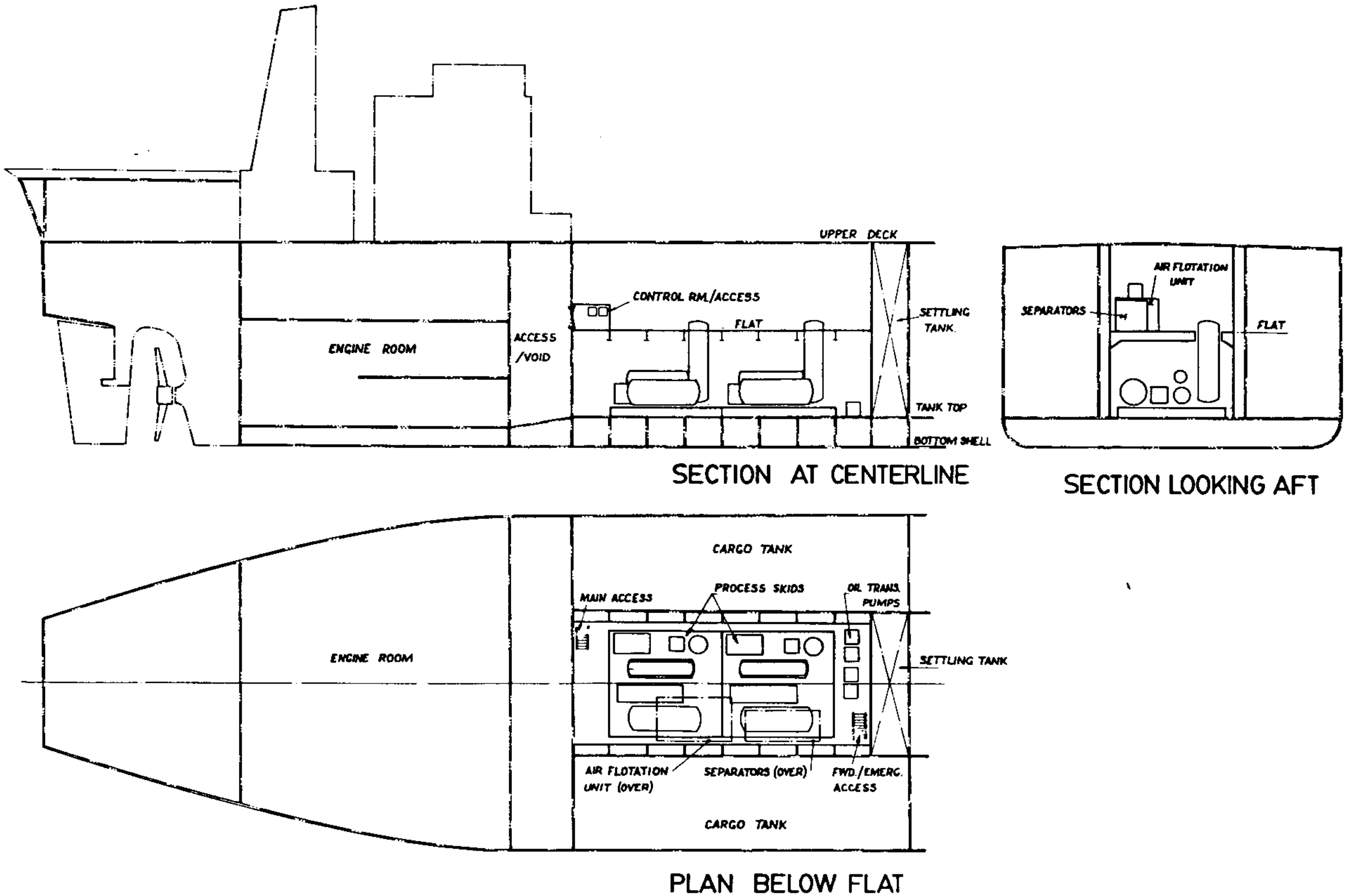


Figure 2.7.2
GENERAL LOCATION OF PROCESS EQUIPMENT

- Water is removed from the oil only to economize on storage, not to meet any given oil quality specification.

- Discharged water is cleaned to meet Coast Guard regulations.

2.11.3 Design Philosophy

Literature surveys were carried out to assess the type of material to be collected by the system. However, such a wide range of possibilities exists that a generic system, undoubtedly with some limitations, has been developed.

Close to the blowout, the oil is expected to be light, collecting in a surface film and rapidly evaporating. The collected oil will require stabilization before treatment or storage to prevent evaporation from creating hazardous vapor conditions. This oil will typically not be emulsified and will separate easily from water.

Oil which has been on the surface 12 to 24 hours will be heavier with much of the light ends evaporated. This oil has begun to emulsify. It will be collected using the skimmers and weir booms without difficulty, but should be stabilized as a precaution.

Oil which has been on the surface for three to four days will be emulsified and could contain about 70 percent water. During rough periods, this oil may be collected along with other oil described above due to wind and current. This oil will be treated with demulsification chemicals and with heat to break down the emulsion. Special provisions are required to keep the skimmers working. One possibility is to circulate hot water/steam to the skimmer to lower the viscosity of the oil water mixture. In this proposal, steam or hot water injection takes place, if needed, at the lift barge at sea level. However, the cost increase for injection at the skimmers and weir boom is considered to be small.

Oil which has been weathered for one week or more will be completely emulsified and stable. Difficulty with the skimmer collectors is anticipated. More severe treatment will be required to break the emulsion. This oil is not expected to be found in the vicinity of the well blowout and would only be encountered during a "mopping up" operation. The rate of pick up would be lower, and it could be treated at a rate that suited the equipment. It is not a governing case for system design.

For the purpose of gravity separation of oil and water, one of the normal cargo tanks will be converted to give a relatively long settling time. Large surface area coalescing media will be used additionally to promote coalescing of dispersed medium droplets. This will give good quality separation for both phases in normal circumstances.

The quality of water recovered from the settling tank should normally be adequate for discharge. However, to ensure meeting offshore discharge standards under normal conditions, a water cleanup plant will be provided. Where the water quantity is greater than the capacity of this unit, and the water cannot be held for later treatment, the settled water could be discharged directly from the settling tank, or run through the unit at greater than its design rate. This would result only in a small loss of quality in the discharge water.

Additional water treatment is provided for a number of reasons. The unit itself is not particularly large or expensive relative to the overall system. By including this unit Coast Guard regulations are complied with for normal operation. In cases where the vessel may be involved in an aftermath clean-up operation the contribution of the water treatment unit to reducing surface oil could be significant. It also provides maximum flexibility for the vessel to assist any any oil spill situation world wide should this be considered desirable.

2.11.4 Process System Description

General

The process system is provided to facilitate separation of water from oil which will reduce storage requirements for recovered oil and incidentally, improve its sale value. Additionally, the system will improve the quality of the discharged water and diminish the damage from any oil not recovered.

Collection System

The oil released from the well will be contained on the sea surface by booms and collected by skimmers.

The low temperature of the sea surface water in winter can cause the oil to lay down wax deposits on collecting surfaces, and will increase the stability of oil-water emulsions. Additionally the oil collected may be quite viscous in spite of its light gravity. The wax and emulsions tend to clog surfaces, causing problems for skimmers, pumps and hoses/flexible pipes. The impact of these problems can be reduced by chemical treatment and by heat application.

Heat application is provided for by bringing a medium pressure (100 psig) steam, or a steam and hot water mixture, as required, from the ship to the lifting barges. The steam/steam and water is transferred by hoseline which will be run and supported together with the 12" oil recovery flexible pipeline. The steam/ water hoses are sized at 6", and at that size, sufficient 100 psi steam can be supplied to raise the temperature of the design flowrate mixture of oil and water by 15^{o}F say from 45^{o}F to 60^{o}F. This requires about 10,000 LBS/HR of steam. This temperature rise is sufficient in all but the coldest conditions, (e.g. Arctic), to melt any wax build up and to reduce emulsion viscosity to manageable levels. The effect of the temperature rise will vary with the specific oil type, but in general terms, this effect will be achieved. General correlations show that a 15^{o}F temperature rise from 45°F to 60°F will reduce 35°F API oil viscosity from 19 to 13 Cp while any material with a solidification point 10°F or more above fluid temperature will have solidified before coming in contact with a surface, and hence will not have a tendency to clog that surface.

There will be some heat loss from the steam hoselines but the rubber hose itself will provide reasonable insulation, and condensation of some of the steam is acceptable. Steam will be supplied at about 100 psi from the ship's system to limit the flowing velocity in the hoseline and to provide energy for mixing, scouring and other operations.

Connections will be provided on the lift barges to transfer the steam to the skimmers for wax and emulsion clearing, and to heat the flow passages that could be clogged with viscous material.

Oil Lifting

Where oil is recovered soon after release from the well blowout, the evaporation rate will be high.

Additionally, the oil will have cooled to sea temperature, but will likely increase in temperature once on board resulting in increased evaporation of light ends. To avoid hazards in the storage tanks, the oil needs to be stabilized to around 13 psi RVP maximum. This can be best achieved by heating the oil, allowing vapor to escape to a safe location, and then cooling the oil to some extent.

Figure 2.11.4 shows the treatment for the fresh oil. Steam is the chosen heating medium as it is readily available on board. A safe location is required for the vent, where it is 50 feet from any potential ignition source, and a point above the tanker's bridge is selected.

Gas Venting

The safety of using atmospheric vents to dispose of flammable vapour has been considered, and found to be in accordance with normal practice used in oil refineries. The vent system should be designed in accordance with API RP 521 Second Edition 1973. Section 4.3.1. 1 deals with formation of flammable mixtures from vapour emissions. The basic criteria for safe vapour discharge conditions is given by the expression (1) on page 26.

$$Re > (1.54 \times 10^4)\rho_j/\rho_\infty \quad . . . . (1)$$

which indicates that jet mixing will occur at the vent exit and concentrations below the flammable limits will be quickly achieved.

In the expression, Re is the Reynolds number of the vapour at the vent stack exit,

ρ_j is the density of the vapour = 0.0788 lbs/cu.ft.

ρ_∞ is the density of air = 0.0765 lbs/cu.ft.

Re $<$ 15,400 x .0788/.0765 = 15,839 is a safe condition.

Crane Technical Paper 410 (Flow of Fluids) page 3.2 gives the following expression (data for stream No. 8 on Figure 2.11.4 - material balance):

$$Re = 123.9\, d\, V \rho / \mu$$

d = internal diameter of the pipe in inches = 6.0

v = gas velocity leaving vent in ft/second = 25.0

ρ = gas density leaving stack in lbs/cu.ft. = 0.0788

μ = dynamic viscosity of gas in centipoise = 0.01

Re = 123.9 x 6.0 x 25 x 0.0788/0.01 = 146,450

This is apprxoimately ten times the minimum value specified in equation (1), hence jet mixing characteristics apply to the conditions taken.

The specific values are a function of the assumptions made for design purposes; however, the detailed design of the facility would optimize the dispersion by using as small a vent pipe as possible, thus maximizing the exit velocity.

The use of a flare to dispose of the released hydrocarbon vapours was not considered for the following reasons:

(a) During normal operation there is unlikely to be sufficient gas to require or to sustain combustion.

(b) The pilot flame system would require a regular and sizable fuel supply to provide reliable ignition under the operating conditions used for a design basis, and provision of this, if possible at all, would be difficult and expensive.

(c) It was considered that an ignition source continuously present on a vessel designed to operate in the vicinity of large flammable gas clouds was contrary to the philosophy of design for the system.

Oil Water Separation

The primary treatment will be by gravity settling. The effectiveness of this is a function of water-oil condition at the inlet, specific gravity of the oil, residence time in the separator, and use of coalescing medium.

Gravity Settling

Under ideal conditions, typical residence times of ten minutes will separate most nonemulsified oil water mixtures. With more than one hour residence time, effective separation is anticipated on almost any system. To achieve this, one of the cargo tanks will be modified to allow several hours residence for the mixture at design feed rates.

As an aid to coalescing smaller water droplets and improving performance, particularly with difficult mixtures, a section of surface active material will be installed. This will be in the form of polypropylene bags installed across the tank, so that the water oil mixture flows through them.

The design incorporates introduction of the oil water mixture at the interface through a sparger to reduce turbulence. The tank will operate full with flow longitudinally. As the phases separate, each phase will pass through the coalescing medium. Water will be withdrawn from the bottom of the tank on interface level control to hold the oil water interface in the center. Oil will overflow a weir at the top to leave the tank. The tank will be kept blanketed with inert gas.

Emulsion Formation

Some emulsification of water in oil or oil in water is anticipated, but is is not quantifiable as it will depend both on the nature of the crude oil and the characteristics of the blowout, i.e. how much energy will be dissipated by the oil in the sea water, and how much sharing of the oil phase will occur. Medium to light paraffinic crudes with moderate to high gas oil ration generally emulsify less than heavy crudes which are aromatic in nature and have greater affinity for water.

Demulsification

Where part of the oil has formed a stable emulsion with sea water, this emulsion must be broken for separation to take place. This is done by heating the emulsion and by mixing with demulsification chemicals, both of which reduce interfacial surface energy, allowing droplet of the dispersed phase to coalesce. This will be done before the gravity settling.

The heating system used for stabilization will provide initial heating for this purpose. Should higher temperatures be required for more stable emulsions, provision is made for injection of steam into the oil water emulsion stream.

In some cases, oil water emulsions are held stabilized by salts dissolved in the water. These are usually emulsions produced from oil wells, and it is not expected that this phenomena will occur with oil in sea water. Such emulsions are treated by fresh water washing, and this is possible if required, consistent with the ship's fresh water production capacity. The fresh water or condensate would be injected into the mixers upstream of the Flash Drum.

Complete treatment of all types of emulsions is not considered practical on a facility such as the Surface Collector Vessel. Treatment to provide for adequate handling of a range of emulsions has been included to ensure that the equipment does not become inoperable due to the presence of emulsions, in most conditions.

There are three primary aspects to treating emulsions and these are in order of importance: heat, demulsification chemicals and settling time.

Heat has been provided first to ensure that the emulsion viscosity will not cause it to clog hoses and piping, then to raise the temperature sufficiently to flash gas, and finally, by direct steam injection, to raise the temperature as required to allow the emulsion to break down. Provision is also made to allow for the addition of whatever demulsification chemicals are found most effective. Finally, the residence time in the settling tank provides for emulsion breakdown.

Should the treatment prove inadequate to break down the emulsions, it is envisaged that the emulsion be stored and transferred to shore for proper treatment. We envisage this requirement in only a small number of potential cases, or as a temporary measure until the right chemical addition for emulsion treatment is identified.

A typical water in oil emulsion would constitute 110 to 125 percent of the volume of the oil and, as such, would provide minimal additional storage problem. Oil in water emulsions can constitute two to three times the volume of the oil, but by nature, they are slower to form, usually being the product of weathered crude and some days of wave action. If significant amounts of oil in water emulsions were recovered and could not be treated lightering to a shore treatment plant on a more frequent basis is required (see section on lightering).

Demulsification Chemicals

These are special chemical compounds which are added in small quantities to the oil water mixture. The specific chemical which will achieve best results, and its optimum concentration have to be determined specifically for each case by testing. As a general guide the concentrations of the chemicals used are in the order of 10 to 50 parts per million, and there are two main generic types, emulsion breakers for treating water in oil mixtures, and reverse emulsion breakers for oil in water mixtures. Either or both of these might be required on any specific occasion. Advice on the specific application of these and other similar chemicals including onsite tests are provided by the manufacturers.

Treatment of Water for Disposal Overboard

Water collected on board with the oil should be discharged overboard after appropriate treatment. This will limit the cargo storage capacity required by the vessel.

The design basis selected is to allow for a water volume equivalent to that of the oil coming onboard. A large portion of this water is expected to be clean sea water collected through the inefficiency of the skimmers and booms in sea conditons close to their operational limits. This will require minimum treatment. Sufficient residence time has been allowed to separate any oil droplets which become entrained with the water due to pumping and flowing in the collection and treatment system. Since the equipment is designed to avoid dispersing the oil into small droplets, the settling time allowed for in the treatment tanks together with the coalescing section provided will be adequate to separate oil droplets in the size range above 50 to 100 microns.

If water coming off the bottom of the settling tanks is found to to be clear of oil, on testing it could be discharged directly to the sea, without further treatment.

To allow for the possibility of excessive dispersion of small oil droplets, additional water treatment equipment has been provided. This includes a Tilted Plate Separator which is capable of removing finely dispersed oil down to less than 100 ppm, and can achieve 50 ppm or less, depending on the condition of the oil in water entering the unit. This type of unit is typically used on offshore installations to achieve the mandatory 72 ppm maximum free oil in water (possibly soon to be reduced to 49 ppm) allowed on the U.S. Outer Continental Shelf (OCS).

Additional treatment has been provided by an Air Flotation Unit which uses air dissolved into the water to collect and coalesce the smallest of all droplets. This unit is generally regarded as 90 percent efficient in removing oil in the inlet water stream. This equipment should reduce the oil content of the water to less than 20 ppm and possibly less than 10 ppm.

Although the Air Flotation Unit effectively produces a water quality higher than the minimum requirement to use in this case is fully justified because of the nature of the treatment. Without using Air Flotation and based on assumed oil content and droplet size range in the water from the Settling Tank, seven (7) vessel would be required to hold sufficient plate packs to achieve the 49 ppm potential limit (three (3) for the 72 ppm level) compared to one required when followed by an Air Flotation Unit.

Information for the sizing of this equipment as provided by equipment manufacturer Engineering Specialties Inc. (ESI) of Covington, Louisiana.

This level of oil in the discharged water is considerably less that the allowable oil content for U.S. OCS production operations and meets the requirement of other more stringent authorities such as Norway. It represents the best available technology for water treating in these circumstances today as discussed earlier.

The equipment provided will operate satisfactorily on mixtures of free oil and water. It is not capable of removing oil dissolved in the water -- this can be up to 20 ppm and is not removable without special physical processing, e.g. distillation or extraction. It does not, however, become visible as a pollutant.

2.11.5 Equipment Description

General

The equipment sequence in the treatment scheme is as follows:

Skimmers/Weir Boom Pumps
Lift Barge/Hot Water or Steam Injection
Ship's Vacuum Tank/Surge Tank
Feed pump
Preheat/Cooling Exchanger
Feed Heater
Stabilize Flash Vessel and Vent Stack

Flash Vessel Pump
Oil Water Separation Tank
Oil Storage Tank
Water Treatment Unit

Additional items of equipment include:

Chemical Injection Skid
Vacuum Pumps

Lift Barge

Described elsewhere, this equipment offers the first opportunity to inject hot water into the collected oil/ water in order to break emulsions and reduce the possibility of heavy wax buildup. Pumps to lift the oil/water mixture on board the ship are provided on the barge, together with breathing apparatus, fire extinguishers, etc.

Lift Barge Steam/Hot Water System

Steam will be supplied at 100 psi through a 6 inch flexible hose line from the ship's steam system. This may be either let down steam or back pressure steam available. Where appropriate, returned condensate may be mixed with the steam to give a steam water mixture. This might be required for jet washing of some overboard equipment, or to dilute some salt water fluid if required.

When used primarily for heating the oil water stream, steam alone would be used. Line sizing is such that a flow of 100 psig steam adequate to heat the design oil water mixture by $15^{o}F$, is provided. To connect the lift barge to the vessel, the steam and oil recovery lines will be run together. To minimize damage due to flexing the lines will be supported such that they cannot be bent tightly. They will be run from a point on the Lift Barge above water level to an entry point on the vessel side convenient to the process equipment location. At the ship side entry points, elbows are provided to allow the hoses to hang vertically.

Ship's Vacuum Tank/Surge Tank

The oil water mixture will be lifted on board primarily by the vacuum, but with assistance from the lift barge pumps. The vacuum pump will pull a vacuum of 10 psi on a tank which will serve both as a vacuum reservoir and a surge tank. It is anticipated that the flow from the lift barge will be uneven, especially in rough weather, and to maintain normal flow to the heater, surge time is provided in the vacuum drum. This is arranged so that the flow can back up into the drum when the treatment rate is less than the feed rate. The vessel size is approximately 10 feet diameter X 40 feet long.

The tank will be fitted with vertical baffles to minimize the effect of vessel motions causing surging of the liquid.

Feed Pumps

Water/oil will be pumped from the surge tank to 20 psi by an axial flow pump requiring about 50 horsepower. This type of pump minimizes sheer energy imparted to the fluid.

Preheat/Cooling Exchanger

The preheat/cooling exchanger is used to recover heat from the oil water stream previously heated up, and to cool the stabilized oil water mixture. This is a shell and tube type unit, about 6'0" diameter and 20' long. Weight is approximately 35 tons.

Feed Heater

This until will use ship's steam supply or waste heat supply to heat the oil water feed by 10 degrees Fahrenheit going to the flash vessel. It will be a shell and tube unit about 3 feet diameter and 20 feet long and weigh 10 tons, heated by steam.

Stabilization Flash Vessel

This will be a vertical vessel giving two minutes residence time for the liquid and an equal vapor space. It will be 8 feet diameter X 30 feet high. The vapors will be exhausted to a vent stack at a location away from any ignition source above the ship's bridge, together with the vent from the vacuum pump outlet, purged by inert gas. There is not expected to be sufficient vapor to warrant flaring (an undesirable operation in these circumstances). The vessel will have horizontal plate and radial vertical baffles to stop liquid surge which could result from ships motions.

Flash Vessel Pump

This unit will be an axial flow pump, to pump the fluid through the feed effluent exchanger to the separation tank. It will require 15 psi discharge pressure and utilize 25 horsepower.

Oil Water Separation Tank

As shown in figure 2.7.2, a central cargo tank is to be used for this purpose. A 12 inch inlet sparger pipe is fitted centrally at one end. A section in the center, covering a cross section through the tank about 4 feet wide, is installed for the coalescing medium which consists of polypropylene shavings called pillows. These are retained in place by grating screens.

A water outlet at the opposite end to the sparger inlet is fitted with a level controller to hold the water interface steady. Above the water outlet, an oil outlet wier is installed.

Oil from here is pumped to the holding/storage tank. This tank is fitted with an inert gas blanket. Vessel motions will have no serious effect on a liquid full vessel. A gentle surging motion through the coalescing medium will be beneficial in promoting settling of the phases.

Oil Storage Tank

Regular ships cargo tanks will be used for oil storage. The total volume of cargo space available for oil storage is in excess of 500,000 barrels (22 days full rate collection) after allowance for the process skid space and the setting tank space.

Water Treatment Unit

This is comprised of a Corrugated Plate Interceptor (CPI) vessel and a gas flotation unit, both proprietary items, to clean up the water prior to overboard discharge. The Air Flotation Unit will have three cells dimensions 25'L X 14'W X 11'H weighing 40 tons full. The CPI will be 13'L X 8'W X 15'H and weigh 28 tons full.

Chemical Injection Skid

This small unit will be capable of injecting up to six chemicals to six different point in the treatment scheme, using a six head individually adjustable plunger type proportioning pump, with a spare pump installed in parallel.

The chemicals which will be supplied in 55 gallon drums will be injected directly from the drums. The drums will be installed in drum supports with prepiped and valved flexible top and bottom connections to the pumps, and with level glasses to show quantities remaining in the drum. The glass will also be calibrated to measure injection rate of the chemical.

The discharge of the pumps will be piped directly to the injection points with a non return valve for protection of the system. An internal pipe distributor will be installed at the injection point.

Vacuum Pumps

These will be motor driven NASH model CL 701 or equivalent capable of pumping 650 cubic feet per minute of gas with a pressure of 7 psi in the Vacuum Surge Drum. A 100% standby unit is provided. The units are equipped with silencers, sea water supplies, and are driven by 35 HP electric motors.

FOSTER WHEELER PETROLEUM DEVELOPMENT LTD.

TITLE:

UTILITY BALANCE

PAGE
OF

POWER	HP	KW
Feed Pump	75	56
Flash Drum Pump	35	26
Oil Transfer Pump	50	37
Water Transfer Pump	75	56
Vacuum Pump	35	26
Flotation Cell	50	39
Total		240
STEAM	DUTY MMBTU/HR	LBS/HR
Lift Flow Heating	12.61	10850
Feed Heater	8.15	9250
Total		20100

MINERAL MANAGEMENT SERVICE
SURFACE COLLECTOR SYSTEM
PROCESS EQUIPMENT

CUSTOMER	Veritec				DOCUMENT No.		
CONTRACT / PROPOSAL No.	1-11-81001						
LOCATION	Houston Tx				DOCUMENT CLASSIFICATION-CLASS:		
REVISION	ORIG.	REV. 1	REV. 2	REV. 3	REV. 4	REV. 5	REV. 6
DATE:							
ORIG. BY:							
CHKD. BY:							
APP. BY:							

CZ-ENII-020/2 REV.0

FOSTER WHEELER PETROLEUM DEVELOPMENT LTD.

TITLE:

PROCESS DATA - TANK

PAGE
OF

ITEM: NO: T1 NAME: SETTLING TANK

PROCESS REQUIREMENTS

FLUID: IN: Oil Water Mixture OUT: TOP Oil
BOTTOM Water

FLOWRATE: Barrels/Day WATER: 48750 OIL: 24040

MINIMUM RESIDENCE TIME (MINUTES) : WATER: 60 OIL: 120

COALESCING MEDIUM: SPACE VELOCITY (HR^{-1}) 12

BLANKETING : Inert Gas

VESSEL DATA

ITEM USED: No 5 Centre Cargo Tank

Volume Ft : Water: 11230 Oil: 11230 Total 22460

INTERNALS

COALESCING MEDIUM: Polypropylene Wool in Sacks Retained by Steel Grating
VOLUME: 2000

INLET : Slotted Pipe Sparger - 12" OUTLET: OIL Wier/Overflow Pipe - 8" WATER Vortex Breaker - 12"

MINERAL MANAGEMENT SERVICE
SURFACE COLLECTOR SYSTEM
PROCESS EQUIPMENT

CUSTOMER	Veritec				DOCUMENT No		
CONTRACT/PROPOSAL No	1-11-81001						
LOCATION	Houston, Tx.				DOCUMENT CLASSIFICATION-CLASS:		
REVISION	ORIG	REV 1	REV 2	REV 3	REV 4	REV 5	REV 6
DATE							
ORIG BY							
CHKD BY							
APP. BY							

FOSTER WHEELER PETROLEUM DEVELOPMENT LTD.

TITLE: PROCESS DATA - WATER TREATING

PAGE OF

UNIT	**TILTED PLATE SEPARATOR (TPS)**	**FLOTATION CELL**
FLOW RATE BARRELS/DAY	48790	48780
MAXIMUM OIL CONTENT IN WATER		
Inlet wt ppm	1070	150
Outlet wt ppm	150	15
OUTLET OIL		
CONDITION	CLEAN	CLEAN
SPECIFIC GRAVITY (API)	0.85 (35°)	0.85 (35°)
PRIOR TREATMENT	Settling Tank/Coalescer	Tilted Plate Separator
TYPE OF UNIT	Plate Pack	Induced Air
NO OF INTERNALS	4 Plate Packs	3 Cells
DIMENSIONS (L.W.H.)	13'-0" x 8'-3" x 15'-0"	25'-0" x 14'-0" x 11'-0"
WEIGH		
lbs Dry/Operating	18500/61500	18000/71000

*DATA SUPPLIED BY ENGINEERING SPECIALITIES INC (ESI) COVINGTON LA 70433

MINERAL MANAGEMENT SERVICE

SURFACE COLLECTOR SYSTEM

PROCESS EQUIPMENT

CUSTOMER:	VERITEC				DOCUMENT No.		
CONTRACT / PROPOSAL No	1-81-0277						
LOCATION:	Houston. Tx				DOCUMENT CLASSIFICATION-CLASS:		
REVISION:	ORIG.	REV 1	REV 2	REV 3	REV 4	REV 5	REV 6
DATE							
ORIG BY:							
CHKD BY:							
APP. BY:							

C7-FNII-02072 REV.0

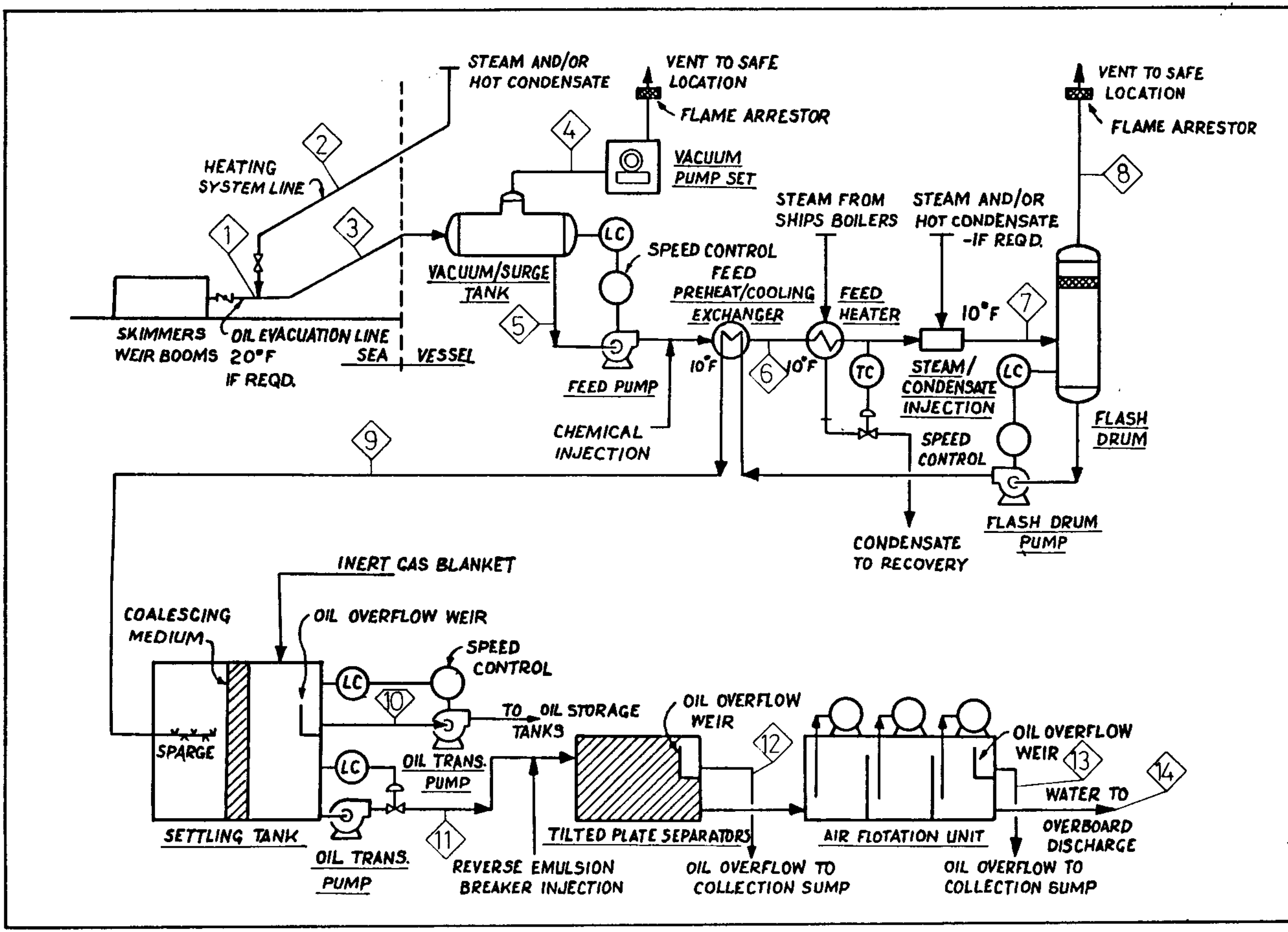
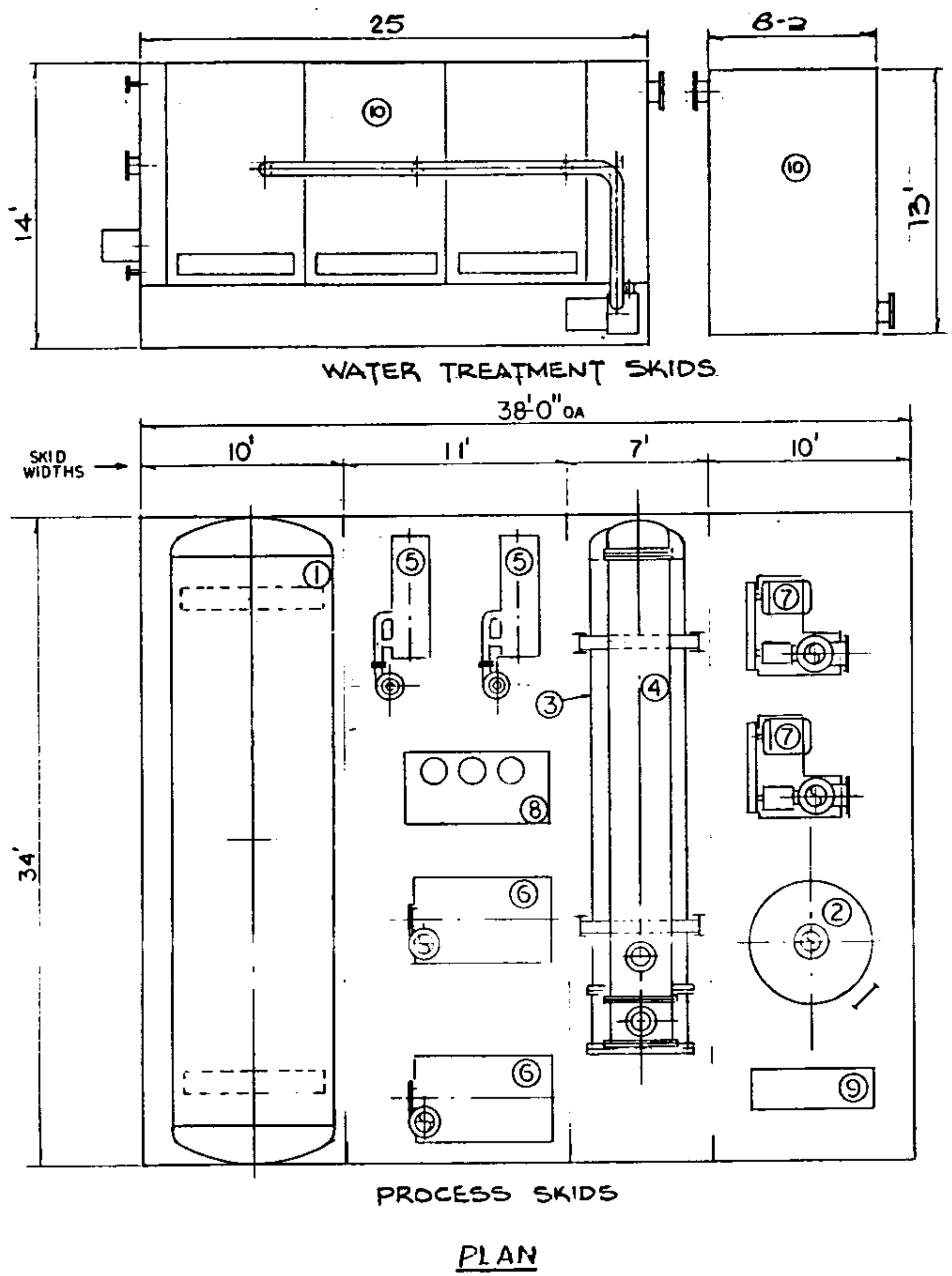


Figure 2.11.4
PROCESS FLOW DIAGRAM
OIL PROCESSING SYSTEM

STREAM No.	1	2	3	4	5	6	7	8	9	10	11	12
FLOW RATE (TOTAL)												
BARRELS/DAY	72000	(830)	72830		72830	72830	72830		72830	24040	48790	9
GALLONS/MINUTE	2100	(24.2)	2124.2		2124.2	2124.2	2124.2		2124.2	700	1424.2	
CUBIC FEET/MINUTE		703		625				300				
TOTAL lb/h	982295	10863	993158	1412	991746	991746	991746	1423	990323	278786	711537	106
GAS lb/h	2795		2795	1398	1397	1397	1397	1397	0			
OIL lb/h	279500		279500		279500	279500	279500		279500	278786	714	106
WATER lb/h LIQUID	700000		710863		710849	710849	710849		710823		710823	
VAPOUR		10863		14				26				
PROPERTIES												
OIL SG	0.86		0.85		0.85	0.85	0.84	0.84	0.85	0.85		0.85
GAS MW	30		30	30	30	30	30	30				
CONDITIONS												
TEMPERATURE °F	45	338	60	60	60	70	80	80	70	70	70	70
PRESSURE psia	30	115	30	7	10	35	25	16	15	15	35	15

( ) = EQUIVALENT

MEAN FLOW RATES
OIL PROCESSING SYSTEM



BILL OF MATERIAL

1. HORIZ. SURGE DRUM
2. VERT. FLASH DRUM
3. FEED/EFFLUENT EXCHANGER
4. FEED HEATER EXCHANGER
5. VACUUM PUMP SETS (2)
6. FEED PUMPS (2)
7. FLASH DRUM PUMPS (2)
8. CHEMICAL INJECTION PKG.
9. CONTROL PANEL
10. FLOTATION CELL
11. TILTED PLATE SEPARATOR

LETTER	DATE	DESCRIPTION
		REVISIONS
		⑧
		⑦ FIELD CONSTRUCTION
		⑥ FABRICATION
		⑤ PREPARATION OF SHOP DETAILS
		④ CUSTOMER COMMENTS
		③ PURCHASE OF ALL MATERIALS
		② PURCHASE OF MAJOR MATERIALS
		① PRELIMINARY ARRANGEMENT
DWG REV.	DATE	ISSUED FOR

MINERAL MANAGEMENT SERVICE

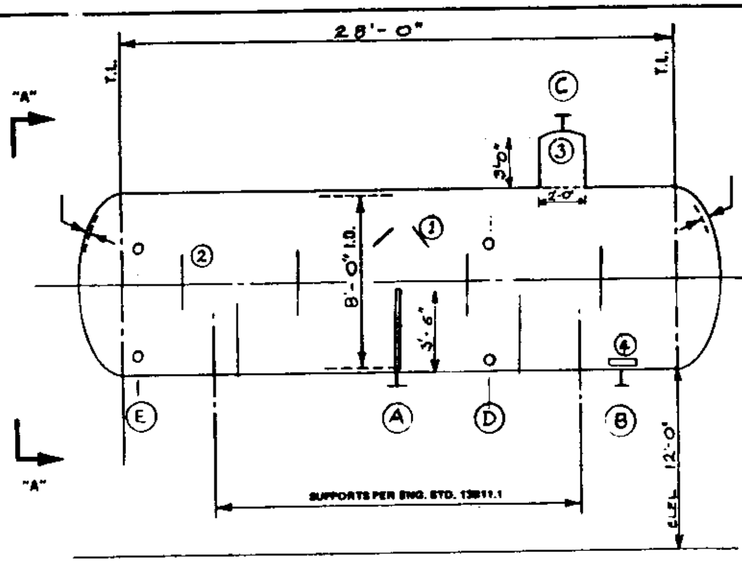
SURFACE COLLECTOR SYSTEM

PROCESS & WATER TREATING EQUIPMENT LAYOUT

FW

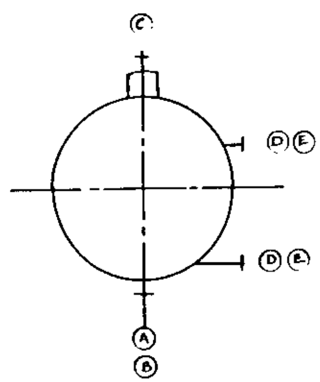
This Drawing is the Property of the FOSTER WHEELER USA CORPORATION 110 SOUTH ORANGE AVE. LIVINGSTON, N.J.

DRAWN BY: | SCALE 1/8" = 1'-0"

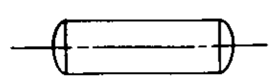


NOTES:

1 - VESSEL FABRICATOR TO SUPPLY AND INSTALL (AS MARKED).
- ☐ PLATFORM AND LADDER ATTACHMENTS
- ☐ PIPE SUPPORTS



VIEW "A - A"



ORIENTATION PLAN

RELEASES

DWG. REV.	DATE	ISSUED FOR
	DATE OF ORDER	PURCHASE SHELL AND HEAD MATERIAL. PREPARE BUT DO NOT SUBMIT SHOP DETAIL DRAWINGS.
		ISSUE CHECKED FOSTER WHEELER DRAWING. PURCHASE ALL OTHER MATERIALS. FINALIZE AND SUBMIT CHECKED SHOP DETAIL DRAWING WITHIN ONE WEEK OF RELEASE DATE. PROCEED WITH COMPLETE FABRICATION.
		FIELD CONSTRUCTION

NOZZLE CHART

CONN. NO.	SIZE	ANSI RATING	SERVICE	NO. REQ'D
A	12"	150	INLET	1
B	12"	150	LIQUID OUTLET	1
C	8"	150	VACUUM OUTLET	1
D	1½"	150	LEVEL GLASS	2
E	1½"	150	LEVEL CONTROL	2

INTERNALS

1	SPLASH BAFFLES	2
2	ANTI SLOSH BAFFLES	
3	VACUUM BOOT	
4	VORTEX BREAKER	

REV.	DATE	BY	DESCRIPTION

REVISIONS

VESSEL DATA

1	ITEM NO: V - 1	NO. REQ'D: ONE
2	SERVICE: VACUUM SURGE DRUM	
3		
4	OPER. PRESSURE ABOVE LIQUID LEVEL	NORM: 5 PSIA
5		MAX: 25 PSIA
6	DESIGN PRESSURE	INT: 50 PSIG
7		EXT: 14.7 PSIG
8	OPER. LIQUID HOLD-UP PRESS.	
9	OPER. PRESS. DROP THRU VESSEL:	0 PSI
10	MAX. RELIEVING PRESS. AT THE TOP HD:	10 PSI
11	MAX. OPER. TEMPERATURE:	100°F
12	DESIGN TEMPERATURE:	150°F
13	SPECIFIC GRAVITY (PROCESS FLUID):	1.0
14	WIND DATA:	NO WIND
15		
16	EARTHQUAKE DATA	VESSEL MOTION
17	CODE:	STAMPED:
18	P.W.H.T. FOR CODE:	FOR PROCESS:
19	RADIOGRAPHED:	
20	JOINT EFFICIENCY:	
21	CORROSION ALLOW./CLAD TK.	
22	MAT'L. SHELL:	
23	MAT'L. HEADS:	
24	MAT'L. SUPPORTS:	
25	MAT'L. FLANGES:	
26	MAT'L. NOZZLES:	
27	EXTERNAL BOLTING:	
28	INTERNAL BOLTING:	
29	GASKETS:	
30	TYPE OF HEADS:	
31	INSULATION:	
32	PAINT: PREPARATION	
33	PRIMER:	
34	COATS:	
35	PARTS:	
36	SHIPMENT:	
37		
38	EMPTY WGT:	
39	WATER (ONLY) WGT:	
40	INSULATION WGT:	
41	GUNITE WGT:	
42	OPER. LIQUID WGT:	
43		
44		

REFERENCE DRAWINGS, REQUISITIONS, STANDARDS

DRAWN
CHECKED
APPROVED

VACUUM SURGE DRUM
SHIP MOUNTED SURFACE
COLLECTOR SYSTEM

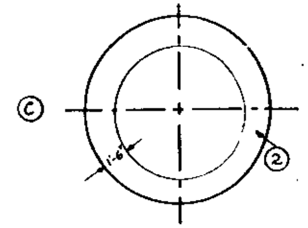
CONTRACT NUMBER: 1-11-00-001001

REQUISITION NUMBER

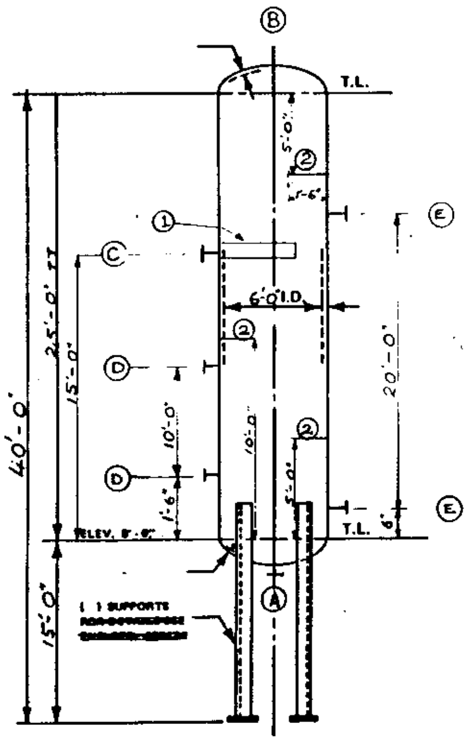
P.O. NUMBER: 14-12-0001-30134

DRAWING NUMBER

REV.



ORIENTATION PLAN



NOTES:

1 - VESSEL FABRICATOR TO SUPPLY AND INSTALL (AS MARKED)

- ☒ PLATFORM AND LADDER ATTACHMENTS
- ☐ INSULATION ATTACHMENTS
- ☐ PIPE SUPPORTS

RELEASES

DWG. REV.	DATE	ISSUED FOR
	DATE OF ORDER	PURCHASE SHELL AND HEAD MATERIAL. PREPARE BUT DO NOT SUBMIT SHOP DETAIL DRAWINGS.
		ISSUE CHECKED FOSTER WHEELER DRAWING. PURCHASE ALL OTHER MATERIALS. FINALIZE AND SUBMIT CHECKED SHOP DETAIL DRAWING WITHIN ONE WEEK OF RELEASE DATE. PROCEED WITH COMPLETE FABRICATION
		FIELD CONSTRUCTION

NOZZLE CHART

CONN NO.	SIZE	ANSI RATING	SERVICE	NO. REQ'D
A	12"	150	LIQUID OUTLET	1
B	6"	150	VAPOR OUTLET	1
C	12"	150	LIQUID INLET	1
D	1½"	150	LEVEL CONTROL	2
E	1½"	150	LEVEL GLASS	2

INTERNALS

1	INLET DISTRIBUTOR	1
2	ANTI SLOSH BAFFLES	3

REV.	DATE	BY	DESCRIPTION

REVISIONS

VESSEL DATA

1	ITEM NO: V-2	NO. REQ'D: ONE		
2	SERVICE: FLASH DRUM			
3				
4	OPER PRESSURE ABOVE LIQUID LEVEL	NORM:	0	PSIG
5		MAX:	5	PSIG
6	DESIGN PRESSURE	INT:	50	PSIG
7		EXT:	14.7	PSIG
8	OPER LIQUID HOLD-UP PRESS:		12	PSIG
9	OPER PRESS DROP THRU VESSEL:		0	PSIG
10	MAX RELIEVING PRESS AT TOP HD:		-	PSIG
11	MAX OPER TEMPERATURE:		125 °F	
12	DESIGN TEMPERATURE		150 °F	
13	SPECIFIC GRAVITY (PROCESS FLUID):		1.0	
14	WIND DATA:		NO WIND	
15				
16	EARTHQUAKE DATA: VESSEL MOTION			
17	CODE:	STAMPED:		
18	P.W.H.T. FOR CODE:	FOR PROCESS:		
19	RADIOGRAPHED:			
20	JOINT EFFICIENCY:			
21	CORROSION ALLOW./CLAD TK:			
22	MAT'L SHELL:			
23	MAT'L HEADS:			
24	MAT'L SUPPORTS:			
25	MAT'L FLANGES:			
26	MAT'L NOZZLES:			
27	EXTERNAL BOLTING:			
28	INTERNAL BOLTING:			
29	GASKETS:			
30	TYPE OF HEADS:			
31	INSULATION:			
32	PAINT: PREPARATION:			
33	PRIMER:			
34	COATS:			
35	PARTS:			
36	SHIPMENT:			
37				
38	EMPTY WGT.			LBS.
39	WATER(ONLY)WGT:			LBS.
40	INSULATION WGT.			LBS.
41	GUNITE WGT.			LBS.
42	OPER. LIQUID WGT:			LBS.
43				
44				

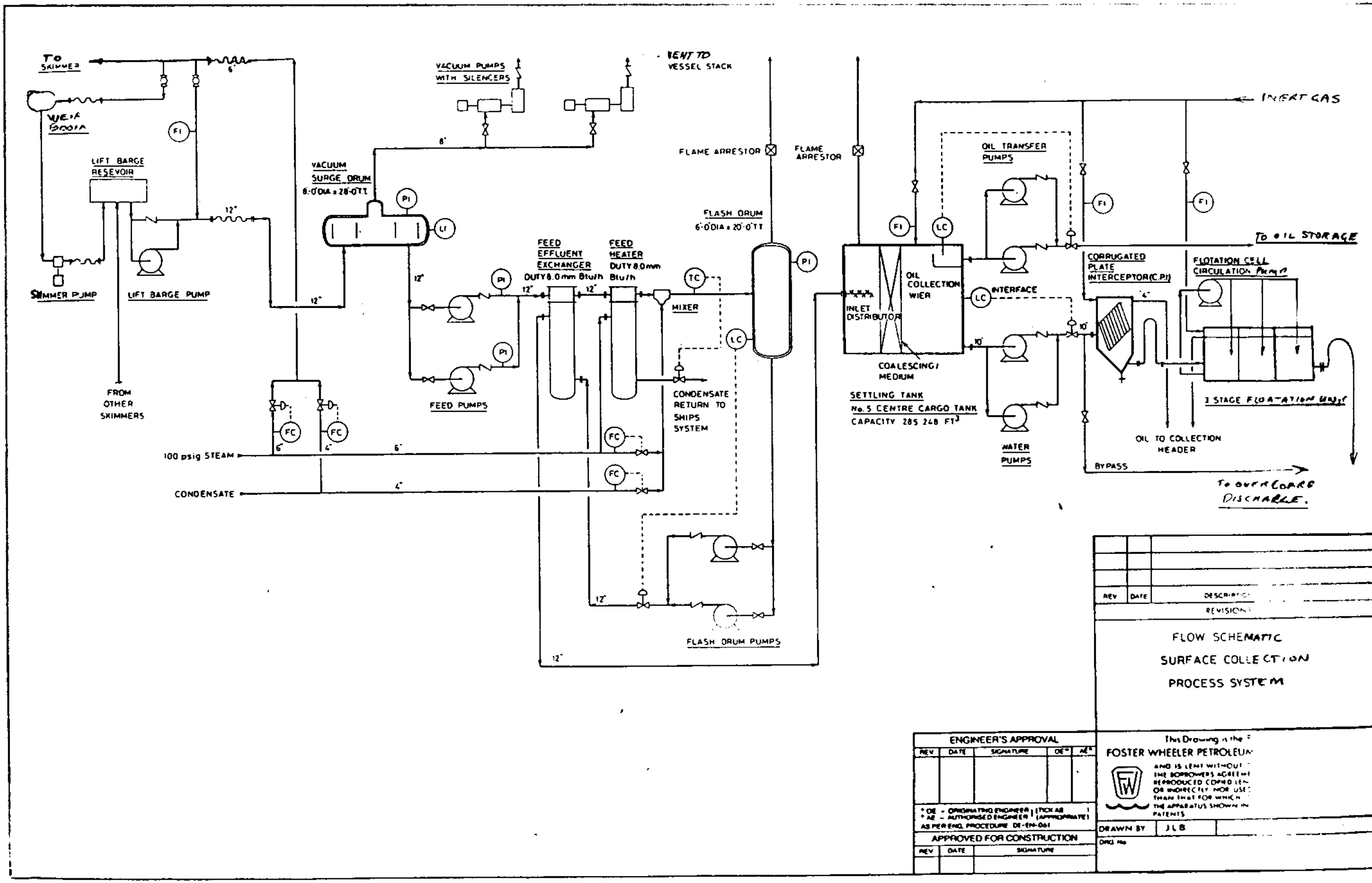
REFERENCE DRAWINGS, REQUISITIONS, STANDARDS			
	DRAWN		
	CHECKED		
	APPROVED		

FLASH DRUM

SHIP MOUNTED SURFACE COLLECTOR SYSTEM

CONTRACT NUMBER	
REQUISITION NUMBER	
P.O. NUMBER	
DRAWING NUMBER	REV.

FORM 126-106


TO SKIMMER
WEIR BOOM
LIFT BARGE RESEVOIR
SKIMMER PUMP
LIFT BARGE PUMP
FROM OTHER SKIMMERS
FI
6"
12"
VACUUM PUMPS WITH SILENCERS
8"
VACUUM SURGE DRUM 6'-0"DIA x 28'-0"T.T.
PI
LI
FC
100 psig STEAM
CONDENSATE
4"
FEED PUMPS
FEED EFFLUENT EXCHANGER DUTY 8.0mm Btu/h
FEED HEATER DUTY 8.0mm Btu/h
TC
MIXER
CONDENSATE RETURN TO SHIPS SYSTEM
VENT TO VESSEL STACK
FLAME ARRESTOR
FLASH DRUM 6'-0"DIA x 20'-0"T.T.
LC
FLASH DRUM PUMPS
INLET DISTRIBUTOR
OIL COLLECTION WIER
COALESCING MEDIUM
SETTLING TANK
No. 5 CENTRE CARGO TANK
CAPACITY 285 248 FT^3
INTERFACE
OIL TRANSFER PUMPS
WATER PUMPS
10"
INERT GAS
TO OIL STORAGE
CORRUGATED PLATE INTERCEPTOR (C.P.I)
FLOTATION CELL CIRCULATION PUMP
3 STAGE FLOATATION UNIT
OIL TO COLLECTION HEADER
BYPASS
TO OVERBOARD DISCHARGE.
REV
DATE
DESCRIPTION
REVISIONS
FLOW SCHEMATIC
SURFACE COLLECTION
PROCESS SYSTEM
ENGINEER'S APPROVAL
SIGNATURE
OE*
AE*
* OE - ORIGINATING ENGINEER (TICK AS APPROPRIATE)
* AE - AUTHORISED ENGINEER
AS PER ENG. PROCEDURE DE-EN-061
APPROVED FOR CONSTRUCTION
This Drawing is the
FOSTER WHEELER PETROLEUM
AND IS LENT WITHOUT
THE BORROWERS AGREEMENT
REPRODUCED COPIED LENT
OR INDIRECTLY NOR USED
THAN THAT FOR WHICH
THE APPARATUS SHOWN IN
PATENTS
DRAWN BY
JLB
DRG No

FOSTER WHEELER ENERGY CORPORATION

Process Plants Division

EXCHANGER

BY DD PROJECT SURFACE COLLECTOR SYSTEM SHEET NO. 1 OF

REV. NO. DATE 2.20.86 UNIT PROCESS SKID JOB NO. 11-81001

ITEM NO.		E1	E2			
ITEM NAME		FEED/ EFFLUENT EXCHANGER	FEED HEATER			
TOTAL TRANSFER AREA (Sq. Ft.)		8000	1000			
NO. OF SHELLS		ONE	ONE			
TEMA CODE TYPE		AEU	AEU			
TUBE	DESIGN TEMP. (°F)	150	350			
TUBE	TUBE LENGTH (Feet) (1)	20	20			
TUBE	DESIGN PRESSURE (PSIG)	50	50			
TUBE	TUBE O.D. (In.) (1)	3/4	3/4			
TUBE	MATERIAL OF CONSTRUCTION	BRASS	BRASS			
SHELL	DESIGN TEMP. (°F)	150	350			
SHELL	DESIGN PRESSURE (PSIG)	50	150			
SHELL	MATERIAL OF CONSTRUCTION	CARBON S. LINED	CARBON STEEL			
DUTY MM BTU/HR		8.0	8.0			

F.W. 130 — 138B

FW

FOSTER WHEELEP ENERGY CORPORATION

Process Plants Division

PUMPS & DRIVERS

BY DD PROJECT SURFACE COLLECTOR SYSTEMS SHEET NO. ____ OF ____

REV. NO. 0 DATE 2.20.86 UNIT Process Skid JOB NO. 11-81001

ITEMS NO.	P1	P2	P3	P4	
ITEM NAME	FEED PUMP	FLASH DRUM PUMP	OIL TRANSFER PUMP	WATER TRANSFER PUMP	
NO. REQUIRED (OPER.)	ONE	ONE	ONE	ONE	
NO. REQUIRED (SPARE)	ONE	ONE	ONE	ONE	
TYPE OF PUMP (Centrip. , Recip. , Etc.)	MIXED	MIXED	CENTRIF	MIXED	
CAPACITY (GPM)	2300	2300	800	1500	
HEAD (Feet)	70	23	50	75	
DRIVER NAMEPLATE (H.P.)	75	40	25	50	
DRIVER TYPE (Motor , Turbine) Main / Spare	MOTOR MOTOR	MOTOR MOTOR	MOTOR MOTOR	MOTOR MOTOR	
DRIVER SPEED (RPM)	3600	3600	3600	3600	
DISCHARGE PRESSURE (PSIG)	30	15	25	35	
FLUID TEMP. (°F)	60	80	70	70	
SPECIFIC GRAVITY	1.0	.99	.84	.99	
FLUID VISCOSITY (Cp.)	2.0	1.7	10	1.0	
MATERIAL OF CONSTRUCTION	C.S.CASING BRONZE IMPELLER	C.S.CASING BRONZE IMPELLER	C.S.CASING AND IMPELLER	C.S.CASING BRONZE IMPELLER	
COMMENTS					

F.W. 130 – 137C

DATA SHEET - SETTLING TANK

Minimum Residence Time	:	Water	60 minutes
	:	Oil	120 minutes
Volume	:	Oil	11,230 $feet^3$
	:	Water	11,230 $feet^3$
		TOTAL	22,460 $feet^3$
Coalescing Medium	:	Polypropylene wool in sacks	
Volume of Coalescing Medium	:	5 minutes residence total: 2,000 $feet^3$	

Internals

Distributer	:	Slotted pipe sparger
Oil Outlet	:	Overflow pipe or wier
Water Outlet	:	Vortex Breaker

Connection Sizes

Inlet	:	12"
Oil Outlet	:	8"
Water Outlet		12"
Gas Blanket	:	6"

DATA SHEET - TILTED PLATE SEPARATOR

Flow Rate	:	48,000 B/D
Maximum Oil at Inlet	:	1,070 ppm wt.
Maximum Oil at Outlet	:	150 ppm wt.
Number of Plate Packs	:	4
Vessel Dimensions	:	13' - 0" long
	:	8'- 3" wide
	:	15' - o" overall high
Weight	:	18,500 lbs empty
	:	61,500 lbs. operating
Oil Gravity	:	35 API (0.85 sg)
Water Gravity	:	1.03
Water Gravity	:	Good - free of sand and wax

DATA SHEET - AIR FLOTATION UNIT

Flow Rate	:	48,000 B/D
Maximum Oil at Outlet	:	15 wt ppm
Maximum Oil at Inlet	:	150 wt ppm
Oil SG	:	0.85 (35^0 API)
Oil Condition	:	Clean
Prior Treatment	:	CPI (Corrugated Plant Interceptor)
Type of Unit	:	Induced air
Number of Cells	:	3
Size of Unit	:	25'- 0" long 14'- 0" wide 11'- 0" high

UTILITY SUMMARY

POWER	HP	KW
Feed Pump	75	56
Flask Drum Pump	35	26
Oil Transfer Pump	50	37
Water Transfer Pump	75	56
Vacuum Pump	35	26
TOTAL		201

STEAM	DUTY MM BTU/HR	LBS/HR
Lift Flow Heating	12.61	10,850
Feed Heater	8.15	9,250
		20,100

2.12 CONTINGENCY PROCEDURES

Procedures are to be developed for two types of situations; those threatening life and those threatening property or the environment.

Overall concern in operating the system is for the protection of life. These are the following principal threats:

1. Sour gas, in almost any concentration.
2. Flammable gas in explosive concentrations.
3. Fire on or around the processing vessel or any of the other vessels.
4. Man overboard, particularly in heavy weather.
5. Injury caused in boom handling or tanker offloading operations.
6. Vessel collision (including helicopters).

Protection of the environment is the principal reason for the operation of the system. Failure of the system is to be anticipated for the following reasons:

1. Environmental conditions.
2. Vessel breakdown.
3. Equipment breakdown, particularly boom failure.
4. Human error.
5. Unusual environmental conditions disperse oil in unexpected manner.
6. Other life threatening conditions occur.

It must also be noted that the failure of any of the emergency systems, e.g., foam monitors, water deluge system, navigation system, propulsion, inert gas system, etc., all result in greater risk of loss of life and contingency procedures must be developed to deal with such situations.

2.12.1 Sour Gas

Abandonment of the collection operation immediately, with all crew donning breathing apparatus is the only option if sour gas is detected. The drilling of a relief well would also have to be undertaken with breathing apparatus, but collection operations, almost inevitably downwind of the blowout, would have to cease. Under no circumstances should this collection operation take place with beer or liquor available to the crew. Alcohol intake dramatically increases the susceptibility of the human body to the fatal effects of sour gas.

Gas, noxious or flammable, will be detected using extensions of the existing systems. The unique nature of the vessel is not adequately covered by current regulations. However, it is anticipated that during operation the entire vessel will be considered similar to a "Zone 1" area under current MODU regulations, i.e., an area in which an explosive gas/air mixture is likely to occur in normal operating conditions. To meet these requirements, the following conversions will be undertaken:

Ventilation: Upgraded to provide positive pressure in all accommodation and crew work spaces, with flash screens over all outlets and intakes, and scrubber on intake ducts.

Accessways: All accessways to be of the airlock type and kept to a minimum. A gas-tight fore and aft accessway leading to foam monitors and fo'c'sl machinery space is provided.

Accommodation: All windows not directly supervised by the watch officer to be non-opening; all external boundaries to be SOLAS AGO.

Machinery: Explosion-proof motors and equipment will be used, with all engines and exhausts suitably insulated and screened.

It is further required that individual breathing apparatus be issued to the crew (ship and service vessels), with 100% spares located in lockers at key working and accommodation areas throughout the vessel.

In the event of a severe sour-gas blowout, it is improbable that the vessel would be able to operate and maintain station. However, in the event of limited or sudden sour-gas presence, it is important that "dry ship" procedures be followed. Personnel with breathing difficulties or who may have taken alcohol in the previous 24 hours must be evacuated immediately from service vessels.

A double helideck is fitted over the aft deck, with a telescopic hanger for permanent helicopter assignment (see figure 2.2.1) to facilitate these procedures.

2.12.2 Flammable Gas in Explosive Concentrations

Operations are intended to take place several hundred feet from the blowout, by which time any unignited gas should be far from explosive in concentration. However, there is the possibility that in times of complete calm, when the collection system has to steam around the blowout in order to build up a collectible depth of oil in the booms, there could be explosive pockets of gas encountered. For this reason and the reason of general comfort, it has been considered prudent to have all hotel quarters and habitable areas of the main vessel positively pressurized. An air scrubber is used, flash screens are provided on all intake ventilators, and windows and doors are refitted to provide good seals and airlocks where necessary.

On the smaller boats, on the lift barges (for times when manned), and on the shuttle tanker, provision of breathing apparatus with sufficient sets of recharging facilities to accommodate 200 percent of the crew is made.

If dangerous concentrations of gas are encountered, a warning is to sound and all crew must put on breathing apparatus and effort must be made immediately to steam away from the area. This applies to each vessel. The boom towing vessels must be expected to sever their towing connections immediately when they detect the problem. These boats have much greater risk of causing an explosion in such circumstances. Since they do not have trained crews, they do not have special precautions to reduce the possibility of sparks, and they do not have the same quality of fire extinguishing systems.

2.12.3 Fire On or Around Any Vessel

The primary vessel has extensive fire extinguishing capabilities. Crew training in the use of this equipment must be very good. Foam monitors and the overall deluge system will be able to cope with most fire situations onboard the vessel above the main deck level. Fires on the water near the vessel will be extinguished using the foam monitors. Fires on the boom towing vessels can also be fought using the equipment on the main vessel. With thruster control and main propulsion equipment, the tanker will be able to get the boom towing vessels in range of the 150 m foam monitors within three or four minutes.

A special burns unit is to be provided in the hospital area of the main vessel. A doctor with burns and injuries experience is to be present for the duration of the cleanup operation (although he would not be on board for normal trading). Another key reason for the permanently located helicopter on the tanker during cleanup operations is to enable injured personnel to be taken to hospital onshore with a minimum of delay.

2.12.4 Man Overboard

A range of emergency procedures are to be practiced regularly in order to cope with the man-overboard situation. The Zodiac boats are to be held in constant readiness during cleanup operations. One standby/-relief boom towing vessel is to be available at all times. No worker should be allowed to work in an exposed location without observation or supervision. This is to avoid the possibility of a man falling in unobserved. It is recommended that survival suits are worn by outside workers in collection operations in exposed locations where water temperature is below 50°F. It is also recommended that where windspeed is in excess of 35 knots, all outside operations should be performed by crew wearing life preservers.

All vessels in the field must be fitted with the latest man-overboard and pickup equipment, including extra davits and nets, poles and ropes.

2.12.5 Injuries Caused in Boom Handling and/or Tanker Offloading

These operations are hazardous simply because heavy equipment must be moved, lines subject to relatively large loads must be passed over the ship's side, and the entire operation takes place in a sea covered with oil. It must be expected that considerable oil residue will accumulate on deck on the smaller boats and on handling equipment, necessitating daily hosing with high pressure water/soap cleaning equipment.

Should an injury occur, the injured person will be treated immediately in the principal collection vessel's hospital area. The standby helicopter will be used to fly the injured person to shore after initial treatment by the onboard doctor.

2.12.6 Vessel Collision

In this section, the possibilities for helicopter accidents and ship collisions are addressed. The helicopter normally stationed on the collector vessel is intended primarily for use in the immediate vicinity of the collection operation. It also serves the function of providing emergency transportation to shore for injured personnel. It must be anticipated that this aircraft is subjected to more than normally hazardous duties in its role in the collection operation. Duties will include: frequent lifting of personnel from small craft to the principal collection vessel and vice versa; frequent reconnaissance of the spreading oil; the demand to take off and operate in heavy weather in the event of some emergency. Foam monitors will be located on the helideck and should be manned for all take-off and landing operations. Powerful lighting will be provided on the collector vessel since a great deal of night time operation is foreseen.

Continuous operation of the standby boat is planned (two boom towing vessels and one standby). "Field" operation of the helicopter should be curtailed when the standby boat is not available. The contingency procedure for helicopter ditching in the field involves this standby vessel proceeding immediately to rescue the crew. The man overboard and pickup equipment must be prepared and readily available for deployment at all times.

A shore-based helicopter must also be on 24-hour standby, dedicated to the collection operation. In the event of a helicopter accident, this standby craft will proceed to the offshore operation immediately.

In the event of vessel collision, where damage is sufficiently serious to cause one or more vessel to sink, it will be necessary to bring in a rescue diving team. Such a capability needs to be identified and put on alert as soon as the first call comes in.

The primary collection vessel will be equipped with a comprehensive workshop, including welding equipment and temporary repair materials, such that it can be used as a central repair facility if collection operations are far from shore and serious damage is caused to any vessel.

In order to minimize the possibility of vessel collision, the primary collection vessel will continuously monitor all vessel positions in the field with a combination of radar and short baseline transponder system. Other vessels will be warned by radio to keep clear of the operation. A five mile radius for a no-go area around the operation is recommended.

2.12.7 Severe Environmental Conditions

When conditions are forecast to deteriorate, or should they exceed Beaufort 5 without warning, oil collection will become inefficient. In this case, before conditions exceed Beaufort 6-7, collection operations will be suspended and the booms and skimmers will be disconnected from the collection vessel and allowed to trail behind the towing vessels. The collection vessel will use its dp system to turn and to provide a lee for the boom towing vessels and the trailing booms. Any small (e.g. Zodiac) boats will be taken back onboard their parent vessels, and the lift barges will be lifted back onboard the primary vessel and secured. Equipment will be pressure hosed off to remove 95 percent of oil contamination as it is retrieved. The retrieval operation will take place out of the area of the oil slick. Estimated time for retrieval of all equipment is four hours.

If conditions are predicted to become severe, say in excess of Beaufort 8, or if Beaufort 6-7 is going to last several days, the booms must be retrieved back aboard the towing vessels, otherwise they will break up in the heavy seas.

Redeployment of these retrieved booms is unlikely to be possible, before they have been taken ashore, cleaned, repaired and repacked. New booms must be deployed in their place.

Redeployment, when environmental conditions have subsided to Beaufort 5 and decreasing, will follow a similar pattern with redeployment estimated to take five hours. Having redeployed all equipment, connecting the trailing booms back to the collection vessel, the complete system will proceed back into the oil collection operation. No attempt will be made to collect oil far from the blowout, although the helicopter and the standby boat can be used to disperse this oil in conditions up to Beaufort 7. However, it is strongly recommended that a separate dispersant operation is mounted from shore, allowing the collection system to concentrate upon performing its primary task.

While waiting for the weather to subside, the field vessels (the primary collection vessel, the two principal boom towing vessels and the standby vessel) will adopt a steaming plan which will provide the maximum benefit of the lee of the large tanker to the smaller three boats. Radar and transponder tracking of all vessel positions from the primary vessel will take place at all times.

Depending upon the blowout location and the weather forecast, all vessels, the primary vessel only, or no vessels may remain near the blowout location. There is no point in forcing the smaller vessels to ride out a hurricane for two days if shelter is available for a few hours steaming away. The logistics of this decision will be carefully evaluated in each case by the Director of Operations.

2.12.8 Vessel Breakdown

The standby vessel is required to immediately replace, or to take in tow, either of the two boom towing vessels should they suffer a breakdown. This standby vessel also has the capability of holding the tanker in position (fore and aft) in the event of main propulsion problems on the tanker. However, in the event of bow thruster failure on the tanker, it is not feasible to continue collection operations in any but the calmest conditions.

Hence vessel breakdown is well covered with the contingency plan.

2.12.9 Equipment Breakdown

The process equipment is relatively straightforward. Breakdown problems are an order of magnitude lower probability than for the collection equipment. In the event of loss of capability in the process equipment, the tanker provides storage capacity for 15 days collection of oil with an additional 100 percent water at a rate of 30,000 bbl/day of oil. Hence lightering operations would be feasible every 12 days in order to offload the tanker without any processing having taken place. However, it must be noted that certain oil/water emulsions will not be handleable unless some heat treatment is used to break the emulsion.

The range of contingency planning for this problem is beyond the scope of this report.

Continuous equipment maintenance problems are foreseen with the collection booms. By their very nature, they are prone to damage during deployment, retrieval and operation. Particular care will be taken to minimize this damage, but abrasion is inevitable. Hence the contingency plan is to have two complete replacement systems, a full range of repair materials and a continuous, inspection and maintenance process during calm weather conditions.

The USCG Strike Team experience with these booms is that it is extremely difficult to retrieve the booms onto any kind of boat without damage occuring to the booms. Nevertheless, some repairs will be possible in calm sea conditions and provision is made for such repairs, replacement of hoses, etc. However, frequent planned replacement forms the basis of the boom operating strategy.

Scheduled boom replacement is shown in figure 2.12.1. Boom replacement, necessitated by boom failure during operation, is shown in figure 2.12.2.

As the commencement of any collection operation, orders for replacement booms should be placed immediately with the boom manufacturers. The minimum order should be for one pair of booms, depending upon delivery schedules, blowout location and blowout rate. The total high seas Skimming Barrier system costs around $140,000 (one system). A replacement boom, with weir pumps but excluding power packs, is around two-thirds of this cost.

An advantage to the selection of this boom is that the USCG Strike Teams also use this equipment. The Gulf Coast Team have four systems, as do the Atlantic Team, and the Pacific Coast Team have twelve. The first line of the defense for replacement systems is to make arrangement with the USCG to use their systems.

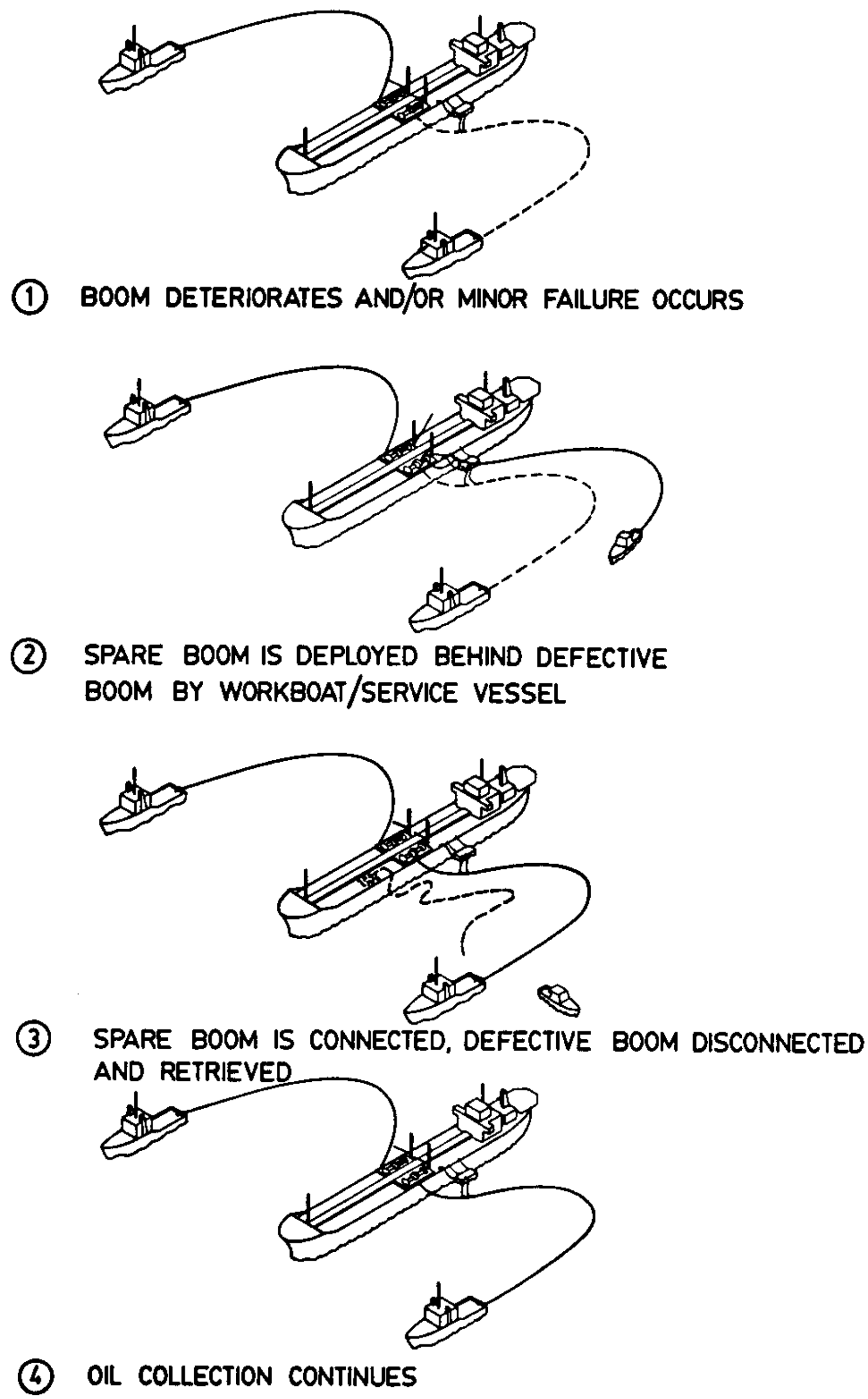


Figure 2.12.1
SCHEDULED BOOM REPLACEMENT

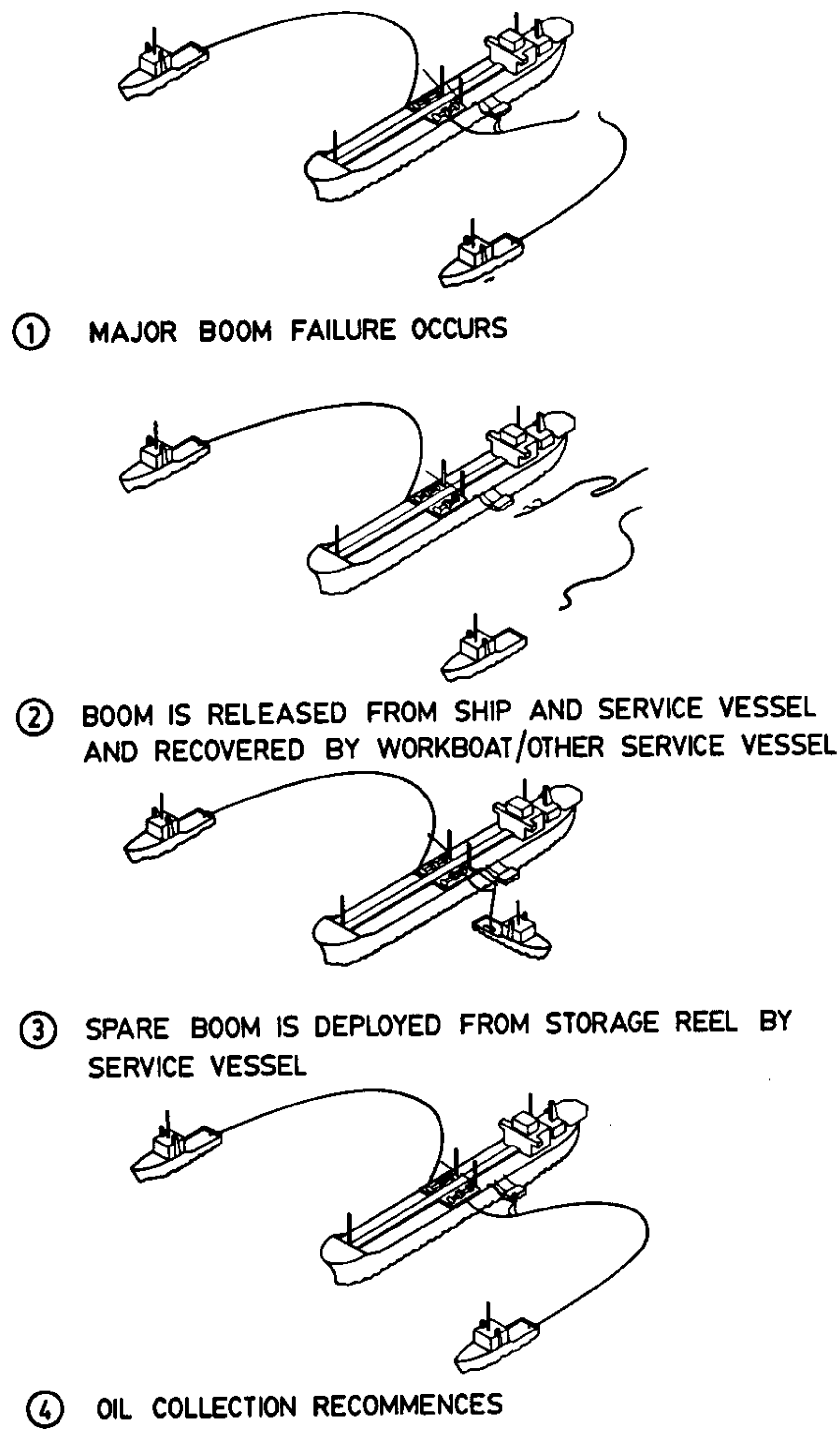


Figure 2.12.2
BOOM REPLACEMENT FOLLOWING BOOM FAILURE

2.12.10 Human Error

Human error can result in vessel collision, equipment loss or breakage, fire, explosions, serious or fatal accidents, man overboard, etc. The plan for avoidance of human error is training, planning, frequent debriefing and progressive planning meetings during operations. Prior to a collection operation, the primary vessel crew will have undergone training and practice operations. **THEY WILL HAVE HAD REFRESHER TRAINING EVERY SIX MONTHS.** At the beginning of the collection operation, the skippers of all other vessels involved will be debriefed and they will brief their crews in the requirements of the operation. Coordination from the primary collection vessel with audio, visual and remote display (radar and transponder systems) will be continuous, 24 hours a day.

No alcohol will be permitted to be consumed during collection operations. This will minimize the consequences of health damage in the event of sour gas pollution of the area, as well as improve human reliability.

2.12.11 Unusual Environmental Conditions

The collection system is intended for continuous use. The optimum conditions are: no waves, 1 knot surface current, 5 knots wind in direction 90^{o} to current. In these conditions the oil from the blowout will be carried by the surface current into the collection system. The gas, if not ignited will be blown away from the collection vessels. If ignited, the flare and smoke from the gas will not cause hazardous conditions either. More probably, however, the environmental condition will be such that the surface current is wind driven and waves will always exist. Thus, the collection operation will be downwind of the blowout and waves will hamper the efficiency of the collection booms and skimmers, cause deterioration of the equipment and eventually (as their height increases) become the limiting environmental factor in the operation.

The ideal and most probable conditions are described above. There are areas where strong currents exist and where surface currents exceed 1 knot, the boom capabilities will begin to deteriorate. In these conditions, the collection system will be forced to "drift" away from the blowout location. At the discretion of the Director of Operations, collection will have to be suspended at some point, and the vessels will move back towards the blowout, where oil concentration on the surface is heaviest, streaming the disconnected boom behind the boom towing vessels. During this period of time, oil cannot be collected and dispersants should be used. Contingency plans in this event of very high current velocities are to narrow the swath and to reduce boom length deployed. Additionally, extra towing points near the midpoint of the booms can be provided. This is a difficult operation in the field, but the possibility exists to modify the booms before deployment to accept additional strong towing points, while offshore, or before new booms are dispatched to the operation.

It is also possible for no surface current and little or no wind to exist for several days at a time. In this case the collector system has to steam around and around the blowout collecting oil as best it can. The big danger in this circumstance may be posed by the gas. It will be very important to keep the flare ignited in order to prevent high concentration of flammable gas drifting into the collection vessels. The contingency plan for doing this is to carry some special remote controlled flare igniters on the principal collection vessel. These non-pyrotechnic projectiles will be deployed as necessary to keep the flare ignited.

2.12.12 Other Life-Threatening Conditions

The above contingency plans cover a wide range of possible scenarios which maintain the operability of the system in adverse conditions. There may be other life-threatening conditions which occur. The plans for dealing with such conditions will be in the hands of the primary collection vessel captain, the captains of the smaller vessels or the overall operations controller. The experience of these individuals and their good seamanship and common sense must substitute for a formal contingency plan.

2.13 OPERABILITY STUDY

California Scenario

The target location is 10 miles off Point Arguello.

From the October, 1983, "Climatic Study of the Southern California Operating Area", prepared by the Naval Oceanography Commancd Detachment, Asheville, North Carolina, the following statistics of waves at the above location have been taken:

PERCENTAGE OF TIME WAVES

	Greater than or equal to 13 Ft.	10-12 Ft.
January	2.7	7.4
February	3.7	6.5
March	2.5	10.7
April	2.9	10.7
May	2.0	10.5
June	2.5	3.2
July	1.2	3.1
August	0.3	2.7
September	0.3	2.9
October	1.7	3.9
November	3.2	4.3
December	2.2	7.7
Average in Year	2.2	6.1

The above figures for wave height include a fairly constant swell component. This component is estimated to be around four feet, on average. The times that waves exceed 12 feet, then, may be crudely judged to be those times where Beaufort 5 is exceeded, producing significant locally wind generated wave heights in escess of 8 feet, which together with the average swell conditions, result in actual wave heights greater than 12 feet. U.S. Coast Guard experience with the boom proposed has shown that the boom performs reasonably well in swell conditions, but it is the short choppy locally generated wind-waves that rapidly become a limiting factor.

For the purpose of this operability estimate, it is considered feasible to operate the system in wave conditions off California tht are up to 10 feet high, being a combination of offshore swell and locally generated waves. Hence, from the preceeding table, it is seen that a downtime not in excess of 6.1% should be caused by waves. Taking account of gradually reducing efficiency as limiting conditions are approached, and allowing for generally lower efficiency at night, we have the following:

* Target efficiency in daylight conditions up to and including Beaufort 5 = 95%

* Allow for a 10% efficiency reduction at night.

* Overall system efficiency in conditions up to Beaufort 5 = 85%

  Percentage of time when environmental conditions cause complete halt = 6%

overall average system operability is then 0.94 X 85 = 80%.

This is to say that a total of 80% of the spill oil may be collected, in an offshore California Scenario. In the Spring, (March, April, May) the previous table shows that this will decline to around 77%, and in summer it will increase to around 82%.

East Coast Scenario

From the Veritas World Atlas, the one year return period maximum and the 100 year return period maximum wave heights have been taken and compared with those given for the area off California. Knowing that the long-term relationships between wave height and number of waves at a given location tend to follow a log linear curve, a simplistic estimate has been made comparing California conditions with those on the East Coast. This comparison predicts a 420 percent greater amount of time when wave conditions will exceed the 2.5m significant height limit for operations. Using this simple relationship, downtime will be expected to be a maximum of around 25 percent by this argument, off Massachusetts. Thus an overall average system operability is found to be 64%, meaning that a total oil may be expected to be collected (75 X 0.85). In winter months on the East Coast, this will decline, to possibly 50%, and in the summer, it will increase, to possibly 70% (based upon engineering and oceanographic experience and judgment).

3.0 COSTS

Some costs were already noted in Section 2.0. Those costs and all others are summarized.

3.1 Cost of Tanker

If the tanker is to be purchased for this project (rather than forming a club of operators, as suggested in Section 2), then, as noted in Section 2.2, the used tanker price will be around $5 million. This assumes a U.S. flag vessel, without coastwise privileges, 90,000 dwt, less than 10 years old, 1985 price.

3.2 Cost of Conversion

In order to realistically price the cost of conversion of the tanker it is necessary to scope out, in detail, the actual degree of retrofit required and accurately access the materials and labor for each step.

General areas of conversion may be defined as follows:

- Hull
- Hull Equipment
- Systems
- Ship Safety

A brief description of the nature and degree of conversion necessary in each of these areas is as follows:

Hull

- Internal tank and structure work; fit side coffers around the midship cargo tank aft (new process room), fit a new transverse bulkhead forward of the new process room to form a large settling tank, and fit a sponson on the starboard side shell aft, to form a ramp for deployment of off-loading hoses.

- Propulsion addition; remove existing structure in way of new thruster sites, remove decks and structure over for installation access, fabricate and fit new thruster wells, tunnels and support structure, reinstall structure removed for access.

- Deck work areas; clear and/or reroute existing structural items, services and fittings, install new deck structure or reinforcement as required, install new internal walkways to suit any access relocation, fit new equipment.

- Walkways and platforms; install new walkways to suit deck arrangement, provide gas-tight enclosure around existing fore and aft walkway, fabricate and fit new foam monitor platforms and accessways, provide access and escape routes to new process room and helideck areas, fabricate and fit boom contains storage areas.

- Boom/oil retrieval equipment, fit hull attachments for boom ends,install mooring points for lift barge and boom end cables, provide deck seatings for lift barges and workboats, provide retrieval area for defective boom storage/ repair.

- Fabricate sliding attachment mechanisms for deployment at ship's sides to attach to booms.

- Oil transfer/off-loading equipment; provide deck area for hose storage, provide foundations for hose handling cranes and winches.

- Additional equipment support, provide all necessary foundations, guide rails, hand rails, support structure and access ability to enable the vessel to best fulfill the mission role.

- Helideck and Hanger; provide helideck, approximately 100 X 75 feet complete with telescopic hanger.

Hull Equipment

- Aft cranes; provide hydraulic telescopic hose-handling cranes on main deck aft, port and starboard.

- Winches; provide winch(es) for handling of off-loading mooring lines, lift barge positioning and defective boom retrieval.

- Hose handling; provide winches and associated tackle for the handling and retrieval of off-loading hoses.

- Positioning equipment; - see Section 2.4.

- Barges and workboats; provide two Lift Barges (as described in section 2.8), provide two workboats suitable for mission-role operations, i.e., boom deployment/replacement, gas ignition, minor crew transfer, spill reconnaissance, etc.

- Spares and accessories; provide sufficient spares and accessories to meet regulatory and mission role requirements.

- Process equipment; fit process equipment to meet mission role requirements.

- Booms and skimmers; provide all necessary oil gathering booms and skimmers (see Section 2.8).

Systems

- Fire and Washdeck; fit all necessary piping, valves, seats, fittings, etc. to provide a main-deck deluge system.

- Foam; provide new monitors, pumps, and protein storage (in process room side coffers) to meet design conditions.

- Fuel oil transfer; if required; refit existing transfer piping to allow refueling of support vessels, fit small stores cranes, or similar, to handle light fuel transfer hoses from support vessels.

- Ventilation; upgrade existing ventilation system to operate effectively and maintain crew comfort under mission role conditions, provide ventilation systems to service new crew, process and enclosed walkway areas.

- Power; supply all necessary power, fuel, hydraulic, water and steam lines.

Safety

See Section 2.6.

Several other factors influencing conversion costs would be dry dock and fitting out wharf costs, cranage, survey and regulatory supervision, technical (engineering) costs and miscellaneous outfitting such as painting - especially important if a long life coating as used to meet on-going survey requirements (to avoid annual survey vessel downtime).

The cost of conversion is derived by evaluating each step of conversion as a series of discrete tasks, and assigning a cost based on materials, estimated man-hours, special equipment usage, drydock or fitting-out wharf time, etc. An example of such an estimate is the cost of fitting hose-handling cranes is shown in table 3.2.1.

Table 3.2.1

STEP	NATURE OF COST	ESTIMATED COST
Fabricate crane foundations	labor	$ 3,000
	materials	$ 4,000
Clear (prepare) deck	labor	$ 1,000
	materials	$ 500
Fit cranes	labor	$ 1,000
	materials	$ 1,500
	survey & test	$ 400
Engineering	design & drafting	$ 2,000
Documentation	admin., instr. booklets, etc.	$ 400
Crane	Purchase equipment	$ 40,000
	Estimated Total cost:	$ 53,800

Although is can be seen that the conversion is actually two discrete areas, i.e., the use or enhancement of existing systems and equipment, a opposed to the fitting of new systems, equipment and structure, for the purpose of cost estimation they have been considered the same and addressed under the general areas of conversion which they effect.

The results of the cost estimation are presented in table 3.2.2.

Table 3.2.2

Operation	Estimated Cost (K)
Hull	
- Internal Tank & structure work	$ 540
- Propulsion addition	Included in Positioning Equipment Costs
- Deck Work areas	$ 84
- Walkways and Platforms	$ 268
- Boom/oil retrieval equipment	$ 37
- Oil transfer/off-loading equip.	$ 61
- Additional equipment support	$ 40
- Helideck & Hanger	$ 336
Subtotal	$ 1.366M
Hull Equipment	
- Aft cranes	$ 40
- Winches	$ 48
- Hose handling	$ 16
- Thruster generators	$ 150
- Positioning equipment	$ 6,400 *See Footnote
- Barges and Workboats	$ 262
- Spares and accessories	$ 100
- Booms (4 High Seas Skimming)	$ 600
- Skimmers (two Walo sep)	$ 300
Subtotal	$ 7.916 M
Process Equipment	
- Process Skid	$ 62
- Process Equipment (see list) inc. Freight	$ 440
- Process Piping	$ 36
- Instruments	$ 33
- Electrical	$ 12.3
- Paint and Insulation	$ 15.4
- Engineering & Procurement, etc.	$ 75
- Water Treating Equipment	$ 197
Subtotal	$ 0.871 M

Operation	Estimated Cost (K)
Equipment List (included in process equipment)	
- Vacuum drum 10 tons @ $3000/ton	$ 30
- Flash Dum 3.3 tons @ $4500/ton	$ 15
- Pumps 4 off at $10,000 inc. drivers	$ 40
- Feed effluent exch. 8000 ft.^{2} @ 30/ft.^{2} for brass tubes	$ 240
- Feed heater 1,000 ft^2 $50 ft^2 (brass tubes)	$ 50
- Chemical injection system	
pumps 3 x 5000	$ 15
tanks & fittings 3 x 1700	$ 5
Systems	
- Fire and Washdeck	$ 25
- Foam	$ 100
- Fuel Oil Transfer	$ 40
- Ventilation	$ 60
- Power	$ 100
Subtotal	$ 0.325 M
Safety	
- Fire Fighting (inc. monitors)	$ 50
- Lifesaving	$ 100
- Breathing Apparatus	$ 30
- Rescue	$ 60
Subtotal	$ 0.540 M
Vessel Preparation	
- Scrubbing	$ 75
- Drydocking	$ 150
Subtotal	$ 0.225 M

Operation	Estimated Cost (K)
Misc.	
- Painting	$ 300
- Engineering	$ 500
Subtotal	$ 0.8 M

Total Estimated Cost of Conversion: $12,043 M

TOTAL CONVERSION COST **$ 13.0 million**
(including survey & regulatory supervision)

*Footnote: Price for thruster retrofit, including positioning system and all associated shipyard costs is based on the following vessel conversions:

M.V. Wilhemen Wilnore, 180,000 DWT Oil Tanker, 1981 cost: $8 million U.S.
M.V. Poly Traveller, 130,000 DWT Oil Tanker, 1981 cost: $6.9 million U.S.
M.V. Poly Trader, 130,000 DWT Oil Tanker, 1982 cost: $6.9 million U.s.

These costs include bow-mounted single point mooring equipment costing an estimated $500,000, giving an estimated 1985 conversion cost of $6.4 million U.S.

3.3 COST OF OPERATIONS

It is envisaged that the recovery vessel will work in any of the above three current areas of major offshore exploration: the Gulf of Mexico, the California Coast and the New England/Eastern Canada Coast.

While sharing many similarities, each of these regions possess unique geographical, economic, and social factors which influence the costs of offshore operations in each area. Examples of these factors would be location of major ports, local fuel costs, current local economy conditions, etc. Although not discussed in detail, factors such as those mentioned here have been considered in estimating operational costs for each area.

Primary factors driving operational costs and the assumptions to determine these costs are listed in Table 3.4.1. This table assumes day rates for Jones Act tankers.

Table 3.4.1

ESTIMATED DAILY COSTS FOR OIL RECOVERY OPERATIONS

COST FACTOR	ASSUMPTION OF COSTS	ESTIM. DAILY COST
Primary Vessel		
Charter Rate	Cost=Charter for Equiv. Vessel X (1+ Conversion Cost) / (Orig. Vessel Cost) i.e. $20,000 X (1 + 051) (see Figure 3.4.2 for original vessel costs)	$30,200
Fuel Costs	Main Propulsion Consumption at 10% output = 8 ton/day Calif. Coast:	$ 5,040
	Thruster Consumption at 50% output = 10 ton/day Calif. Coast:	$ 5,040
	Hotel & Machinery Load = 500 KW/HR = 3 ton/day N.E. Coast:	$ 4,995
Lightering Vessel	Jones Act Vessel similar in size to primary vessel	
Charter Rate	$20,000 day, exc. fuel	$ 20,000
Fuel Cost	$20,000 HP M.C.R. = 74 ton/day Calif. Coast:	$ 17,760
	Gulf Coast:	$ 17,760
	N.E. Coast:	$ 17,390
Service Vessel	Vessel size: 140-180 ft. Power: 2000-4000 HP, 3 required	
Charter Rate	Day rate, exc. fuel Calif. Coast:	$ 4,950
	Gulf Coast:	$ 4,950
	N.E. Coast:	$ 6,000
Fuel Cost	Propulsion consumption at 30% output = 3 ton/day Calif. Coast:	$ 2,304
	Hotel Load: 70 KW/HR = 0.2 ton/day N.E. Coast:	$ 2,256

COST FACTOR	ASSUMPTION OF COSTS		ESTIM. DAILY COST
Supply Vessel	Similar in size and characteristics to service vessel. Two trips per week.		
Charter Rate	Equivalent day rate, exc. fuel allowing for actual usage not being continuous.	Calif. Coast:	$ 236
		Gulf Coast:	$ 472
		N.E. Coast:	$ 707
Fuel Cost	3,000 M.C.R.	Calif. Coast:	$ 253
		Gulf Coast:	$ 506
		N.E. Coast:	$ 759
Aircraft Support	Bell 412 or similar		
Base Rate	$100,000 per month retainer, exc. fuel		$ 3,333
Operational Flying	8 hrs. per day at $600/hr.		$ 4,800
Operational Fuel Cost	8 hrs. per day at $600/hr.		$ 1,610
Trip Flying	2 trips per week	Calif. Coast:	$ 171
		Gulf Coast:	$ 343
		N.E. Coast	$ 514
Trip Fuel Costs	115 gls/hr. X $1.75 retail cost	Calif. Coast:	$ 58
		Gulf Coast:	$ 115
		N.E. Coast:	$ 173
Communications	Commercial rates		$ 1,400
Personnel Costs			
Medical Team	1 doctor @ $500/day, 2 med. assts. @ $250/day each		$ 1,000
Overall Coordinator	$500/day		$ 500
Oil Scientists	2 @ $350/day		$ 700

n.b. All prices are current 1985 rates and costs.

Estimated Daily Operating Costs:

California Coast:	$94,315 per day
Gulf Coast:	$95,033 per day
N.E. Coast:	$96,337 per day

With a non-Jones Act tanker and without loading the charter rate with the conversion cost, the collection operations costs drop by $18,000 day. If it is intended to trade the primary vessel on a commercial basis, a further cost factor is the cost of a replacement vessel to take over the route and duties of the primary vessel. Also to be considered would be any contractual penalties for failure to pick up, or deliver, any cargoes outstanding at the time of well blow-out. If the collection vessel was owned by the operators, the charter rate would not apply and total daily operating cost would be $94,000 to $96,000.

3.4 INVESTMENT ANALYSIS

The cost to purchase the tanker and convert it is around $18 million. To borrow this money would cost $1.8 million per year. If the system sat idle for two years before a job, it would have cost a total of around $22 million.

If a tanker engaged in regular trade was converted, the conversion cost plus interest would amount to a total of around $16 million after two years. There is also the cost for crew training and vessel upkeep, calculated to be approximately $1.8 million per year.

What cost then is the environmental damage and revenue loss if a collection operation is not undertaken? Of course, this depends upon where the blowout is. However, off California it could be assumed to be in excess of several hundred million dollars.

The collection operation costs become:

Investment cost plus interest:	\$22 million
Maintenance cost over 2 years:	\$ 3.6 million
150 days operations @ \$62,737:	\$ 9.3 million
150 days additional interest :	\$ 1.1 million
TOTAL	\$36.0 million

With the conversion and operation of a ship in service, this cost could be reduced to \$29 million, even allowing for a \$20,000/day charter rate during collection.

Value of oil collected, with full blowout rate of 30,000 bpd, \$20/bbl sale price, 70 percent effiency would be: \$30,000 x 20 x 150 x 0.7 = 63 million.

Note that the value of the collected oil will be dependent not only upon market conditions but also upon the location of the blowout, the type of oil, the success of the separation process, and the volume of oil for sales. Thus the above payback assumptions, and those that follow, are based upon a nominal \$20.00/bbl price. Events of 1985/87 have shown that the market price for oil cannot be reliably predicted. Nevertheless, the exercise is instructive in that it demonstrates that there is a good chance that the system could be paid for with a single large blowout event.

Now consider other blowout rates and shorter periods in time. The result of revenue from selling the oil is shown in $millions in Table 3.4.1 below:

Duration	Rate in bbl/day				
(Days)	30000	20000	10000	5000	1000
150	63	42	21	10.5	2.1
100	42	28	14	7	1.4
50	21	14	7	3.5	.7
25	11.5	7	3.5	1.7	.3

Table 3.4 Recovered oil value in $millions

In conclusion, it can be seen that the suggested blowout scenario occurring within two years of vessel conversion results in a handsome payoff. The probability of success and the value of the investment are improved if an existing ship in service is converted and operated.

4.0 REFERENCES

(1) R. S. Platou: "The Platou Report," March 1985.

(2) A. L. Burbank & Co. Ship Brokers.

(3) "Federal Region II Regional Contingency Planning for a Dispersant Decision Process," R. F. Corbin and A. L. Ott, Oil Spill Conference, 1985, Los Angeles.

(4) "Dispersants: Comparison of Laboratory Tests and Field Trials with Practical Experience at Spills," J. A. Nichols and H. D. Parker, Oil Spill Conference, 1985, Los Angeles.

(5) "Advance Planning for Dispersant Use/Non-Use," J. P. Fraser, Oil Spill Conference, 1985, Los Angeles.